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PROGRAMME OF THE CHICAGO MEETING

AT

CHICAGO, ILLINOIS

November 25–26, 1949

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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

1949 THANKSGIVING MEETING AT CHICAGO, NOVEMBER 25–26, 1949

THE 295th meeting of the American Physical Society will be held at Chicago, in the buildings of the University of Chicago, on Friday and Saturday, November 25 and 26, 1949. This will be the largest meeting yet held at Chicago, exceeding by one-third in number of papers the corresponding meeting of 1948. (The magnitude of this convention raises the question whether in years to come we shall not be obliged to extend our Thanksgiving meeting into Sunday.) We shall use Mandel Hall (at the southwest corner of 57th Street and University Avenue); Breasted Hall (at the southeast corner of 58th Street and University Avenue); Eckhart Hall and Kent Theatre (on the north side of the line which 58th Street would follow if projected across the campus); Rosenwald Hall (opposite the façade of Eckhart Hall); and Judd Hall (on the east side of Kimbark Avenue south of 58th Street). It is regretted that the size of the meeting prevents us from reserving Friday afternoon for a single session, as was done in 1948.

The **registration desk** will be in Room 209 of Eckhart Hall. Dinner tickets will be sold there. All members and guests are asked to register there, and frequently to consult the bulletin board for notice of messages.

Hotel. Rooms have been reserved for our members at the Sherman Hotel, downtown at the corner of Randolph and Clark Streets. In writing for a reservation, mention that you are coming to the meeting of the American Physical Society. Allow forty-five minutes to go eastward from the hotel to the station of the Illinois Central Railroad at Randolph Street and Michigan Boulevard, thence by train to the station designated as "55th-56th-57th Street," thence from the 57th-Street exit of this station westward half-a-mile to the University of Chicago.

Invited papers on the general programme will be given by Bernard Abraham, H. H. Barschall, E. C. Bullard, J. G. Daunt, C. O. Muehlhouse, L. A. Ridenour and Arthur Roberts. To a certain extent the papers of Messrs. Daunt and Ridenour will be derived from the great conferences on cryogenics and on computing machines held at Cambridge (Massachusetts) in the month of September.

Invited papers on solid-state physics will be given by H. Y. Fan, J. R. Haynes, J. H. Hollomon, Peter Pringsheim and C. G. Shull.

Invited papers on electron-emission and on gaseous electronics, constituting two Symposia of the Division of Electron Physics, will be given by E. A. Coomes, H. C. Early with W. G. Dow, A. S. Eisenstein, E. O. Johnson with L. Malter, L. R. Walker, A. H. Weber and J. G. Winans.

One hundred and forty-four **contributed papers** are distributed among thirteen sessions.

The **dinner of the American Physical Society** will be held on the Friday evening at the Shoreland Hotel, on the lake front north of 55th Street: the price will be four dollars. Advance reservations are particularly requested, so that advance notice may be given to the hotel of the number to be expected; use the form printed on the inside back cover page. Tickets will be held at the registration desk until 3 P.M., after which those which remain will be sold to the first comers. If you wish your tickets mailed to you, send a check (made out to the American Physical Society) and do not omit to give your address. After-dinner talks will be given by S. K. Allison and E. C. Bullard.

The **Council of the American Physical Society** will meet at 10 A.M. on Friday in Eckhart 316.

Post-deadline papers. The Council or its designates will consider the admission, to a special supplementary programme, of a limited number of additional papers of which the abstracts reach the office of the Society not later than Friday 18 November. Do not regard this as a guarantee of acceptance! The idea is to make possible the presentation of very recent achievements of very special

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importance. The abstracts of such post-deadline papers as are accepted will not be published; the titles will be announced on the bulletin-board at the registration desk, and the papers will be given at the end of Session T.

Announcement pertaining to "Physics Today." Gratuitous distribution of the journal "Physics Today" to members of the Society will end with the December issue of this year. Those who wish to receive it thereafter at $4 per year ($5 for members overseas) should promptly send word to that effect to PHYSICS TODAY, 57 East 55th Street, New York 22, N. Y. Cards for this purpose will be provided in every issue of the journal for the remainder of 1949.

Prospective meetings of the Society are scheduled as follows: Stanford University, California, December 29–30; New York City, February 2–4, 1950; Oak Ridge, March 16–18; Washington, D. C., April 27–29; Mexico City, June 21–24.

General Rules Relating to Papers

The time allowed for the oral presentation of a contributed paper is ten minutes at most. The time allowed for the oral presentation of each invited paper is stated in the Bulletin.

When two or more papers are contributed by the same member, all but one are placed on the "supplementary programme." (A paper by two or more members is credited, for this purpose, to the person first named in its by-line.) For each paper on this programme a session is indicated, at the end of which it may be offered: but the presiding officer may require that it be given in fewer than ten minutes, or may read it by title.

Titles and abstracts of the papers contributed to the Chicago meeting are printed in the following pages. Proofs of the abstracts have not been submitted to the authors, and the proofreading is always cursory because of the need for haste: but the authors have opportunity to correct their proofs before the abstracts appear in the *Physical Review*. Overlong abstracts sometimes appear in a form unexpected by the authors, because there is not time to consult them before the abstracts are amputated to fit the requirements stated on the summons card.

Speakers must not forget to retrieve their lantern slides at the end of the session at which they are used. The Local Committee is in no wise obligated to keep or to return them.

Karl K. Darrow, *Secretary*
American Physical Society
Columbia University
New York 27, New York

EPITOME OF THE MEETING

(Personal names are those of invited speakers)

Friday Morning

A. Band and microwave spectroscopy. Eckhart 133.
B. Artificial radioactive substances. Breasted Hall.
C. H. H. Barschall, C. O. Muehlhouse, Bernard Abraham. Judd 126.
D. Electron emission; A. H. Weber, E. A. Coomes, A. Eisenstein. Mandel Hall.

Friday Afternoon

E. Gaseous electronics: J. G. Winans, E. O. Johnson, L. Malter, L. R. Walker, H. C. Early, W. G. Dow. Rosenwald Hall.
F. Invited papers of general interest: E. C. Bullard, L. A. Ridenour, J. G. Daunt. Mandel Hall.
G. Optical physics; line-spectroscopy; nuclear magnetic resonance; mass spectrometry. Eckhart 133.
H. Artificial radioactive substances; radioactivity of the neutron; capture and scattering of neutrons. Kent Theatre.
J. Solid-state physics. Breasted Hall.

Friday Evening

Dinner of the American Physical Society. 7 P.M., Shoreland Hotel. S. K. Allison, E. C. Bullard.

Saturday Morning

L. Solid-state physics: H. Y. Fan, J. R. Haynes, C. G. Shull, J. H. Hollomon. Kent Theatre.
M. Cosmic rays and artificial mesons; Arthur Roberts. Mandel Hall.
N. Reactions of transmutation. Eckhart 133.
P. Miscellany of nuclear experiments; nuclear theory. Rosenwald Hall.

Saturday Afternoon

S. Nuclear and general theory. Rosenwald Hall.
T. Apparatus of nuclear physics; crystal counters. Kent Theatre.
U. Semiconductors; miscellany in electron physics. Eckhart 133.
V. Peter Pringsheim; papers not classed elsewhere. Breasted Hall.

PROGRAMME

Friday Morning at 9:45

Eckhart 133

(R. S. Mulliken presiding)

Band and Microwave Spectroscopy

A1. Raman Spectrum and Force Constants for Fluorotrichloromethane. James P. Zietlow, Forrest F. Cleveland, and Arnold G. Meister, *Illinois Institute of Technology.*— Raman displacements, semi-quantitative relative intensities, and precise depolarization factors were obtained for liquid CCl_3F. Assignments were made for the fundamental frequencies, and fourteen force constants in a modified valence-force potential function were obtained. The constants of the CCl_3 group were transferred from CCl_3H and CCl_3D, and the other constants were evaluated from the observed frequencies, as was done previously for CCl_3Br.[1] Further proof of the transferability of these constants was obtained by calculating the frequencies of carbon tetrachloride, with a maximum difference between observed and calculated values of 1.7 percent. Below are the Raman displacements $\Delta\nu$ in cm^{-1}, the relative intensities I, the depolarization factors ρ, and the calculated displacements $\Delta\nu_c$. The calculated displacements are identical with the mean of all $\Delta\nu$ values thus far obtained (present results included).

	$\nu_6(E)$	$\nu_3(A_1)$	$\nu_5(E)$	$\nu_2(A_1)$	$\nu_4(E)$	$\nu_1(A_1)$
$\Delta\nu$	247	352	399	538	837	1066
I	25	30	15	100	5	1
ρ	0.83	0.42	0.81	0.11	—*	—*
$\Delta\nu_c$	244.6	350.5	397.8	535.8	835.4	1068.1

* The bands obtained up to now are too weak for precise measurement of ρ.

[1] Zietlow, Cleveland, and Meister, Phys. Rev. **75**, 333 (1949).

A2. Vibrational Spectra and Calculated Thermodynamic Properties of Deuterotrichloromethane. JOHN R. MADIGAN, FORREST F. CLEVELAND, WILLIAM M. BOYER, AND RICHARD B. BERNSTEIN, *Illinois Institute of Technology.*—Raman displacements $\Delta\nu$ in cm^{-1}, semi-quantitative relative intensities I, and quantitative depolarization factors ρ for the liquid, and infra-red frequencies ν for the liquid and CS_2 solution at different concentrations, in the region 400–5000 cm^{-1}, have been obtained for $CDCl_3$. The present $\Delta\nu(I)\rho$ values for the liquid were: 262(100)0.87; 365(92)0.10; 649(72)0.03; 735(14)0.84; 908(3)0.87; 2255(05)0.26, and the ν values for the solution were: 648; 727; 756; 904; 2247 cm^{-1}. No previous infra-red data or quantitative depolarization factors were found for this molecule. The infra-red band at 2247 was obtained with NaCl optics and the others with KBr optics. A band observed at 1202 is caused by *ca* 8 percent $CHCl_3$. The broad infra-red band at 735 cm^{-1} was resolved into the doublet 727, 756 for dilute solutions. Heat capacity, heat content, free energy, and entropy were calculated at temperatures of 298.06°, 300°, 400°, 500°, 600°, 700°, 800°, 900°, and 1000°K. The values for 298.16°K were: $C_p=16.40$ cal. deg.$^{-1}$ mole^{-1}, $(H-H_0)/T=11.56$ cal. deg.$^{-1}$ mole^{-1}, $-(F-F_0)/T=49.66$ cal. deg.$^{-1}$ mole^{-1}, and $S^0=61.22$ cal. deg.$^{-1}$ mole^{-1}. Thermodynamic calculations and infra-red investigations are also being carried out on $CHCl_3$, $CBrCl_3$, and CCl_4.

A3. Vibrational Spectra and Calculated Thermodynamic Properties of Deuterotribromomethane. SALVADOR M. FERGILE, FORREST F. CLEVELAND, WILLIAM M. BOYER, AND RICHARD B. BERNSTEIN, *Illinois Institute of Technology.*—Raman frequencies and intensities have been given for CBr_3D by Redlich and Stricks.[1] No depolarization factors or infra-red data have been found in the literature. As a part of the work on substituted methanes and ethanes that is being carried out in this laboratory, Raman displacements, semi-quantitative relative intensities, depolarization factors, and infra-red frequencies have been obtained for CBr_3D. The Raman frequencies are in good agreement with the values previously reported. Depolarization factors have been measured with a Leeds and Northrup Recording Microphotometer. Infra-red spectra have been run with both NaCl and KBr optics. Depolarization factors for CBr_3H and CBr_3Cl have also been obtained and thermodynamic properties for all the tribromomethanes have been calculated to a rigid rotator, harmonic oscillator approximation.

[1] O. Redlich and W. Stricks, Sitz. Akad. Wiss. Wien, IIb, **145**, 192 (1936).

A4. Raman and Infra-Red Spectra of 1,1,1-Trichloroethane. M. ZAKI EL-SABBAN AND FORREST F. CLEVELAND, *Illinois Institute of Technology.*—Raman displacements $\Delta\nu$, semi-quantitative relative intensities I, and quantitative depolarization factors ρ for the liquid, and infra-red frequencies ν for both liquid and gaseous states in the region 400–5000 cm^{-1} have been obtained for $H_3C\text{-}CCl_3$. The present $\Delta\nu(I)\rho$ values for the liquid are: 242(45)0.86; 344(74)0.58; 523(100)0.12; 544(vw); 698(vw); 710 and 721(19)0.84; 1073(3) and 1083(3)-0.82; 1383(1); 1422(2) and 1449(4)0.81; 1789(w); 2740(1); 2880(2); 2938(80)0.15; and 3005(21)0.81 (w = weak, vw = very weak). The only depolarization factors previously reported are those by Wagner, whose $\Delta\nu(I)\rho$ values were: 240(90)0.81; 308(0?); 342(99)0.48; 522(100)0.03; 690(0); 713(49)0.78; 760(0); 1068 and 1082(12)0.64; 1179(w?); 1378(w); 1420 and 1444(9)0.81; 2740(w); 2938(29)0.32; 3002(25)0.97. The 713 cm^{-1} line was resolved into the doublet 710,721 cm^{-1} in the present work. The infra-red data, ν (percent absorption), were, for the liquid: 523(70); 688(11); 708(75); 786(61); 858(19); 950(16); 1000(38); 1075(91); 1224(45); 1366(60); 1423(59); 1960(12); 2938(28); 4300(6); and for the gas: 525(70); 534(64); 709(92); 734(84); 796(23); 863(18); 964(13); 1007(36); 1082(99); 1242(23); 1372(58); 1435(43); 2062(3); 2954(13). These seem to be the first infra-red data for this molecule, except for the band at 343 cm^{-1} reported by Hyde. Calculation of force constants and thermodynamic properties is now in progress.

A5. Raman and Infra-Red Spectra for Hexachloroethane and Hexabromoethane, and Force Constants for Hexachloroethane. ROSE A. CARNEY,* ARNOLD G. MEISTER, AND FORREST F. CLEVELAND, *Illinois Institute of Technology.*—Infra-red data in the region 400–5000 cm^{-1}, and Raman frequencies, relative intensities, and depolarization factors, are reported for solutions of hexachloroethane and hexabromoethane. Critical evaluation was made of all the Raman data obtained for these molecules, including previous data, in order to set up tables of "most probable values." However, since no previous infra-red data were found in the literature, only the results of the present investigation were available when the calculations were started. These, then, were the values used in determining, by a normal-coordinate treatment, the force constants for hexachloroethane that would give the best fit with the observed vibrational frequencies, assuming a D_{3d} symmetry. Recently Mizushima[1] and his co-workers have obtained the near infra-red spectrum of hexachloroethane and their results are in good agreement with those obtained in the present investigation. Calculation of the force constants for hexabromoethane is in progress.

* Now at St. Procopius College, Lisle, Illinois.

[1] Mizushima, Morino, Simanouti, and Kuratani, J. Chem. Phys. **17**, 838 1949).

A6. Raman and Infra-Red Spectra of 2,3-Dibromo-2,3-Dimethylbutane. J. E. LAMPORT AND FORREST F. CLEVELAND, *Illinois Institute of Technology.*—Using methods described earlier,[1] Raman displacements, relative intensities and depolarization factors for solutions of 2,3-dibromo-2,3-dimethylbutane were obtained. Kahovec and Wagner[2] had previously obtained the Raman spectrum of the compound in the powdered crystalline state. Eleven Raman displacements were found by Kahovec and Wagner, while eighteen have been found in the present investigation. A comparison of the results of this investigation with those of Kahovec and Wagner will be made. Ten frequencies have been observed in the infra-red absorption spectrum using a Beckman Model IR-2 infra-red spectrophotometer equipped with KBr optics, covering the range from 400 to 5000 cm^{-1}. The fact that none of the intense infra-red absorption bands correspond to strong Raman lines is taken to indicate a center of symmetry for the molecule. This is further borne out by the appearance of only 18 Raman lines for a molecule of 20 atoms which should have 54 fundamental vibrations. There are also fewer infra-red absorption bands than is normal for a molecule of this size.

[1] Forrest F. Cleveland, J. Chem. Phys. **11**, 1 (1943); **13**, 101 (1945).
[2] L. Kahovec and J. Wagner, Zeits. f. physik. Chem. **B47**, 48 (1940).

A7. Band Spectrum of GaCl. F. K. LEVIN* AND J. G. WINANS, *University of Wisconsin.*—The absorption spectrum of GaCl showed vibrational but no rotational structure in the 2490A to 2700A system, $^1\Pi_1 \leftarrow {}^1\Sigma_0{}^+$. The predissociation limit indicated a dissociation energy for the ground state 4.99 ± 0.01 volts. A short continuum at 2430A indicated $^1\Pi$ causing predissociation. Vibrational analyses of $^3\Pi_1 \leftrightarrow {}^1\Sigma_0{}^+$ and $^3\Pi_0 \leftrightarrow {}^1\Sigma_0{}^+$, systems 3200A to 3500A gave constants:

$\omega_e''=365.3$ cm^{-1}, $\omega_e''x_e''=1.2$ cm^{-1} for $^1\Sigma_0{}^+$.
$\omega_e'=395.3$ cm^{-1}, $\omega_e'x_e'=2.3$ cm^{-1}, $\omega_e'y_e'=0.015$ cm^{-1}, $\nu_e=29{,}524.3$ cm^{-1} for $^3\Pi_0$.
$\omega_e'=395.3$ cm^{-1}, $\omega_e'x_e'=2.5$ cm^{-1}, $\nu_e=29{,}856.3$ cm^{-1} for $^3\Pi^1$.

Rotational constants obtained are:

$B_0''=0.1490$ cm^{-1}, $D_0''=2.4\times10^{-8}$ cm^{-1},
$B_1''=0.1487$ cm^{-1} for $^1\Sigma_0{}^+$.
$B_0'=0.1568$ cm^{-1} for $^3\Pi_1$.
$B_0'=0.1568$ cm^{-1}, $D_0'=2.4\times10^{-8}$ cm^{-1} for $^3\Pi_0$.

* Now with Carter Oil Co., Tulsa, Oklahoma.

A8. Absolute Absorption Coefficients in N_2 in the Vacuum Ultraviolet.* G. L. WEISSLER AND E. I. MOHR, *University of Southern California.*—Absolute absorption coefficients k_λ in N_2 for light of 600A to 1300A were measured in a grazing incidence two-meter vacuum spectrograph of average dispersion of 3A/mm using Eastman 103-0 plates sensitized for the u.v. with a fluorescent lacquer. A Lyman source provided the wave-length continuum. On a single plate two exposures were taken at known, different pressures of N_2 in the spectrograph, five overlapping exposures were taken in a high vacuum. In addition this plate contained two series of calibration exposures using Schneider's** method. The exposure ratios were monitored by electronically counting the number of Lyman flashes. In spite of reaming of the capillary by the discharges this proved to be reliable. The overlapping exposures provided for a check at various wave-lengths of the characteristic curve of the plate obtained by the Schneider method. Nine plates were taken providing 27 independent determinations of k_λ as a function of wave-lengths. A modified Zeiss microphotometer is used in the evaluation of the plates. Preliminary results will be presented. Work on other gases is in progress.

* Supported by ONR.
** F. G. Schneider, J. Opt. Soc. Am. **30**, 129 (1940).

A9. The Absorption of Radiation in the Very Near Infra-Red by Water Vapor.* ROBERT M. CHAPMAN, *The Ohio State University (Introduced by Dudley Williams).*—A quantitative experiment study was made on the infra-red absorption of the water vapor bands at 1.35μ and 1.85μ using a low dispersion prism spectrometer. The effect on the absorption of changing the water vapor concentration, changing the absorption path length by means of a multiple reflection absorption cell, and increasing the total pressure by the addition of dry air were investigated. It was found that the average fractional absorption in each band, A fits the theoretically derived expression,[1,2] $A=erf(t)=\frac{2}{\sqrt{\pi}}\int_0^t e^{-t^2}dt$, in which $t=[1/2\beta(\pi w)^{\frac{1}{2}}f(p)]$, β is a generalized absorption coefficient for each band, w is the water vapor concentration in precipitable centimeters of water, and $f(p)$ is a function of pressure alone. An analysis of the data permitted evaluation of the form of the pressure function $f(p)$ as $f(p)=[(P_t+P_p)/760]^{\frac{1}{2}}$, where P_t is the total pressure in the absorption cell, in mm of Hg; and P_p is the partial pressure of the water vapor, in mm of Hg.

* The work described in this paper was carried out, in part, under contract between the Engineer Research and Development Laboratories of the Engineer Center, Ft. Belvoir, Virginia, and The Ohio State University Research Foundation.
[1] W. M. Elsasser, Harvard Meteorological Studies No. 6 (1942).
[2] T. G. Cowling, Rep. on Prog. in Physics **9**, 29 (1942).

A10. Microwave Spectrum of Methyl Alcohol.* D. K. COLES, W. E. GOOD, AND R. H. HUGHES, *Westinghouse Research Laboratories.*—The microwave spectrum of CH_3OH is complicated by hindered rotation of the O—H group around the CH_3 axis. We have measured and identified 59 lines of $C^{12}H_3OH$ and $C^{13}H_3OH$ in the frequency interval between 16,900 Mc and 34,000 Mc. A short *series* of lines in the neighborhood of 25,000 Mc was first noticed by W. D. Hershberger. B. P. Dailey made more extended observations. D. M. Dennison suggested that the series was due to simultaneous internal and over-all rotational transitions in which the quantum number J does not change. We have employed the Stark effect to identify early lines in the series and have been able to follow the series from $J=2$ at a frequency of 24,934.38 Mc up to $J=20$ at 31,358.31 Mc and then down to $J=30$ at 16,941.6 Mc. $C^{13}H_3OH$ and $CH_3O^{18}H_3$ have been prepared. The corresponding series for the C^{13} molecule has been followed from 27,052.97 Mc for $J=2$ up to 33,220.05 Mc for $J=20$, and down to 17,870.5 Mc for $J=31$. It is hoped that the additional information provided by the O^{18} substitution will make possible a complete determination of the molecular structure.

* This work was supported in its entirety by the Westinghouse Electric Corporation.

A11. Microwave Spectrum of Nitrosyl Chloride.* W. J. PIETENPOL, J. D. ROGERS, AND DUDLEY WILLIAMS, *The Ohio State University.*—The microwave absorption spectrum of nitrosyl chloride has been observed by means of a recording Stark spectrograph. The transitions $1_0\rightarrow 2_{-1}$, $1_{-1}\rightarrow 2_{-2}$, and $1_{+1}\rightarrow 2_0$ have been observed for each of the two chlorine isotopes Cl^{35} and Cl^{37}. Rotational constants determined from these transitions are $A(Cl^{35})=5.3136$ cm^{-1}, $B(Cl^{35})=0.19001$ cm^{-1}, $C(Cl^{35})=0.18345$ cm^{-1}, and $A(Cl^{37})=5.6765$ cm^{-1}, $B(Cl^{37})=0.18900$ cm^{-1}, $C(Cl^{37})=0.18291$ cm^{-1}, and agree quite favorably with electron diffraction[1] data. This shows NOCl to be nearly an accidentally symmetric top with asymmetry constant being $b(Cl^{35})=-0.00064$ and $b(Cl^{37})=-0.00055$. Hyperfine structure observed for these lines a quadrupole coupling coefficient of $-eQq(Cl^{35})=62\pm6$ Mc/sec. and $-eQq(Cl^{37})=50\pm8$ Mc/sec. The Stark effect for Cl^{35} has been observed and follows the law $\Delta\nu=\alpha E^2M$, where $\alpha=5.45\pm0.05$ cm^2/sec. volts.[2] Centrifugal stretching has been obtained to account for shift of lines from their normal positions.

* The work reported was done under a contract between O. S. U. Research Foundation and Watson Laboratories of the Air Materiel Command, Red Bank, New Jersey.
[1] Ketelaar and Palmer, J. Am. Chem. Soc. **59**, 2629 (1937).
[2] H. H. Nielsen, Phys. Rev. **38**, 1432 (1931).

A12. Pressure Broadening and Line Shift in Microwave Spectra. L. C. JONES, *St. Louis University (Introduced by A. V. Buskovitch).*—Approximate formulas for pressure broadening and line shift have been derived for an absorber surrounded by N_j foreign perturbers located at r_j with respect to the absorber, and N_i non-foreign perturbers at r_i, assuming the resonant interaction potential is of the form $a_ir_i^{-3}$, and the non-resonant potential is of the form $b_jr_j^{-6}$. Orders of magnitude are computed for the average interaction coefficients, the line shift and the ratio of half-width to shift for carbonyl sulfide (OCS) perturbed by cyanogen chloride (ClCN) and ammonia (NH_3) perturbed by methyl chloride (CH_3Cl).

A13. Nuclear and Molecular Information from the Microwave Spectrum of FCl. D. A. GILBERT AND A. ROBERTS, *State University of Iowa.*—The triplets due to the $J=0\rightarrow1$ rotational transitions in FCl^{35} and FCl^{37} have been observed near 30,000 mc both for the ground vibrational state and the first excited vibrational state. Stark effect measurements give for the molecular dipole moment 0.88 Debye. Observed deviations from the predicted hyperfine structure spacings may be explained by assuming an interaction[1] of the form $cI\cdot J$, where $c\cong0.03$ mc for FCl^{35}. The ratio $B_e^{37}/B_e^{35}=30{,}378.468/30{,}967.404$ yields for the Cl^{35}/Cl^{37} mass ratio 0.9459771 $\pm$0.0000036, agreeing better with the previous determination in ICl,[2] 0.9459801$\pm$0.000005 than with the best mass-spectroscopic values,[3] 0.9459445$\pm$0.000007. We conclude that the latter is probably in error. The vibration-rotation constants are $\alpha^{35}=130.696\pm0.02$ mc and $\alpha^{37}=126.972\pm0.02$ mc. The quadrupole coupling constants are $eqQ^{35}=-146.00\pm0.12$ and $eqQ^{37}=-144.89\pm0.13$. Their ratio agrees only moderately well with that found by Davis and Zabel.[4]

[1] W. Nierenberg and N. F. Ramsey, Phys. Rev. **72**, 1075 (1947).
[2] Townes, Merritt, and Wright, Phys. Rev. **73**, 1334 (1948).
[3] Recalculated from Okuda *et al.*, Phys. Rev. **58**, 578 (1940) with H and C masses from K. T. Bainbridge, *Isotopic Weights of the Fundamental Isotopes* (National Research Council, Washington, D. C., 1948).
[4] L. Davis and C. W. Zabel, Phys. Rev. **74**, 1211A (1948).

A14. Nuclear Spin and Quadrupole Coupling of S^{35}.* VICTOR W. COHEN, WALTER S. KOSKI, T. WENTINK, JR., *Brookhaven National Laboratory.*—The rotational transition

$J=1\rightarrow 2$ of COS^{35} has been observed at a frequency of 23461 ± 5 mc using a Stark modulation microwave spectroscope operating at 100 kc. The observed pattern is consistent with a nuclear spin of S^{35} of $\frac{3}{2}$. The quadrupole coupling constant is observed to be $+20\pm 4$ mc/sec. Comparison of this with S^{33} which also has a spin of $\frac{3}{2}$[1] shows the signs of the two quadrupole coupling constants is opposite. This reversal of the sign of the nuclear quadrupole moment in going from S^{33} to S^{35} is in accord with the theory of shell structure and electric quadrupole moments as described by Townes, Foley, Low,[2] and Hill.[3]

* Work performed at Brookhaven National Laboratory under contract with the AEC.
** Permanent address: Chemistry Department, Johns Hopkins University.
[1] Townes and Geschwind, Phys. Rev. **74**, 622 (1948).
[2] Townes, Foley, and Low, Phys. Rev. (to be published).
[3] Hill, Phys. Rev. **76**, 998 (1949).

FRIDAY MORNING AT 10:00

Breasted Hall

(A. LONGACRE presiding)

Artificial Radioactive Substances

B1. Ra DEF Standard Sources for Beta-Disintegration Rate Determinations. T. B. NOVEY, *Argonne National Laboratory.*—Ra DEF equilibrium sources for absolute beta-counting have been prepared and calibrated. The sources are essentially weightless and are mounted on a thin backing to avoid self absorption and backscattering correction problems. The sources were calibrated by determination of the alpha-disintegration rate of the Ra F in a parallel plate alpha-ionization chamber. No secondary standards are required and the sources can be recalibrated at any time. As an example of the application of such standards, details of the calibration of a P^{32} solution distributed by the Bureau of Standards for intercalibration in February, 1949 will be given. The final result is 88.8 mrd/ml at 8 A.M., C.D.T., March 1, 1949. The precision of the measurement is 0.3 percent. The accuracy is estimated to be 1–2 percent.

B2. The Production of Li^8 from Various Gases. S. COURTENAY WRIGHT, *University of California, Berkeley.*—Li^8 has been produced by 340-Mev proton and 190-Mev deuteron bombardments of C, N, Ne, A, Kr, and Xe. The target element formed the gas of a proportional counter. The 0.88-second beta-decay of Li^8 produces Be^{8*} which disintegrates into two alpha-particles with a half-life of 10^{-21} second. Li^8 was detected by observation of these alpha-particles and identified by its half-life. Deuteron excitation functions for the production of Li^8 are given for C, N, Ne, and A. In the case of 190-Mev deuterons the cross section varies from about 10^{-27} cm² for C to 2×10^{-29} cm² for Xe. For 340-Mev protons the variation is from about 7×10^{-27} cm² for C to 3×10^{-29} cm² for Ce. A discussion of the process involved is given.

B3. γ-Rays from N^{16}. C. H. MILLAR, A. G. W. CAMERON, AND M. GLICKSMAN, *Chalk River Laboratories.*—The energies and relative intensities of the γ-rays from N^{16} have been measured with deuterium loaded emulsions. The source was the effluent cooling water of the Chalk River pile. The reaction is presumed to be $O^{16}(n, p)N^{16}$. An Ilford C2 emulsion (100 μ-thick) containing 0.40 mg/cm² deuterium in the form of hexadeutero diacetin was used to register photo-proton tracks. The plate was exposed to 2 r of γ-rays at the end of a lead collimator and then developed normally. Background tracks were measured in an unirradiated plate from the same batch. Measurements of α-particle tracks from contamination in the emulsions showed that the stopping power was 7 percent less than in standard C2 emulsions. The range-energy relationship given by Lattes *et al.*[1] was accordingly modified and used. A histogram of the photo-proton tracks indicates γ-rays at 6.2 and 7.0 Mev, in agreement with the well-known excitation energies 6.16 and 7.06 Mev[2] of O^{16}. The relative intensities of the γ-rays are 6:1 respectively.

[1] Lattes, Fowler, and Cuer, Proc. Phys. Soc. **59**, 885 (1947).
[2] See, for example, Rasmussen, Hornyak, and Lauritsen, Phys. Rev. **75**, 1462 (1949).

B4. Beta Spectra of Cl^{38}. LAWRENCE M. LANGER,* *Los Alamos Scientific Laboratory.*—The beta-spectra of the 38-minute Cl^{38} activity have been studied in a magnetic lens spectrometer. The source was 10 mg/cm² of NH_4Cl which was irradiated in the thermal neutron column of a nuclear reactor. Three distinct groups of beta-rays were observed. The highest energy group was found to have a shape characteristic of a once forbidden transition. The shape is completely satisfied by the forbidden factor $W^2-1+(W_0-W)^2$. This suggests that the transition involves an angular momentum change of 2 units and a parity change. Because of the low atomic number and the high maximum energy, W_0, this conclusion is not as uniquely determined as in the case of a heavier element.[1] However, from the theory of nuclear shell structure,[2] one would expect a parity change and a change of *at least* 2 units of angular momentum. The end-point energies and the branching ratios of the three groups are: 4.81 Mev, 53.4 percent; 2.77 Mev, 15.8 percent; 1.11 Mev, 30.8 percent.

* Indiana University.
[1] L. M. Langer and H. C. Price, Jr., Phys. Rev. **75**, 1109 (1949).
[2] M. G. Mayer, Phys. Rev. **75**, 1969 (1949).

B5. Nuclear Gamma-Radiation from Positron Emitters.* H. E. KUBITSCHEK,[1] A. LONGACRE, AND M. GOLDHABER, *University of Illinois.*—Absorption measurements of low intensity gamma-radiation from positron emitters are complicated by the annihilation radiation present. Spectroscopic methods are preferred, but these become tedious in the search for unknown radiation, since the lifetimes of positron emitters are usually short. A simple absorption technique has been devised which permits a more rapid survey. The source, thin to self-absorption for positrons, is placed in a vacuum chamber. Positrons escape to the chamber walls to produce annihilation radiation from which the detector can now be shielded. In this manner the nuclear gamma-radiation of Cu^{64} was substantiated. With 0.1 ml foils the detection of annihilation radiation was reduced to 4 percent of the maximum observable with a thick source. Measurements on Ti^{45} showed the existence of two gamma-rays, of 0.51 ± 0.02 and 0.82 ± 0.03 Mev. The ratio of the number of positrons to 0.5-Mev gamma-rays to 0.8-Mev gamma-rays was $(19\pm 2):(4.1\pm 0.8):(1)$. Verification for these gamma-rays was obtained from the photo electron spectrum obtained with a 180° spectrometer. The energies

were 0.48±0.02 and 0.80±0.01 Mev. A Kurie plot of the positron spectrum gave an end point of 1.00±0.02 Mev.

* This work was supported by the ONR. Service irradiations of copper were done by Oak Ridge National Laboratory.
[1] Atomic Energy Commission Fellow.

B6. The Shape of the Positron Spectrum of Cu^{61}. GEORGE E. OWEN AND C. SHARP COOK,* *Washington University.*—The remaining low energy excess of particles in the allowed beta-spectra have been assumed to be caused by the finite thickness of the source. In order to test this, a source of Cu^{61} has been prepared by evaporation from a tungsten filament onto an aluminum foil backing. The thickness calculated from the activity of the source was of the order of magnitude of $(10)^{-4}$ micrograms per square centimeter. This thickness corresponds to less than one complete atomic layer. The resulting spectrum gives a Fermi-Kurie plot identical with those previously obtained using chemically deposited sources and still shows an excess of positrons in the region below 500 kev. Although the aluminum backing was much thicker than the source, evidence will be shown indicating that the backings used most probably do not produce the deviations observed. Attempts are being made to obtain a comparable source of Cu^{64} and the results from this isotope will be reported if available at the time.

* Assisted by the Joint Program of the ONR and AEC.

B7. On the Disintegration of Sr^{85}.* MICHEL TER-POGOSSIAN, *Washington University.*—The disintegration of the 65-day Sr^{85} was studied in a 180° β-ray spectrometer. This isotope has been previously reported to decay by K-capture with emission of a gamma-radiation of 0.8 Mev.[1] The source was prepared by bombarding a sample of rubidium chloride with deuterons in the Washington University cyclotron, and by separating chemically the strontium after addition of carrier. The source was found to emit a single gamma-radiation of 0.510±0.005 Mev partially internally converted. This energy was obtained by measuring the energy of secondary photo electrons emitted by a uranium radiator placed in front of the source and by measuring the energy of the internal conversion electrons emitted by the source. Two groups of low energy electrons were found to be emitted by the source, corresponding to Auger electrons emitted from the L and M shell of the daughter atom. Any attempt to detect the presence of positrons failed. The fact that no coincidences were observed between the photons emitted by the source at 180° ruled out the possibility for the observed radiation to be due to the annihilation of positrons.

* Assisted by the Joint Program of the ONR and AEC.
[1] DuBridge and Marshall, Phys. Rev. Phys. Rev. **58**, 7 (1940).

B8. Assignment and Disintegration Scheme of the 6.75-hour Molybdenum Activity. D. N. KUNDU, JOHN L. HULT, AND M. L. POOL, *Ohio State University.*—A redetermination of the assignment of the 6.75-hour Mo activity was undertaken because (1) contrary to the observations of others that this activity was produced by Mo+d, no measurable amount of this activity could be produced by our 10-Mev deuterons even from enriched Mo^{92}; (2) $Mo^{92}+n$ and $Mo^{94}+\gamma$ has been found not to produce this activity.[2] The 6.75-hour Mo activity is still attributed to Mo^{93} by virtue of the reactions $Cb^{93}(p, n)$, $Cb^{93}(d, 2n)$, $Zr^{90}(\alpha, n)$, $Zr^{91}(\alpha, 2n)$, and $Mo^{93}(n, 2n)$ using enriched isotopes in the last three cases. A disintegration scheme has been worked out using absorption, beta-ray spectrograph and coincidence counter measurements. The decay does not take place by positron emission or K-capture. After the emission of three gamma-rays of energies 0.30, 0.70, and 1.7 Mev in cascade of which the first is about 90 percent internally converted, the 6.75-hour Mo^{93} passes into a long-lived isomeric state. MoK_α x-rays resulting from the conversion have been found. The absence of the (d, p) and (n, γ) reactions may be related to the fact the Mo^{92} is a nucleus with the magic number 50 neutrons.

[1] M. L. Wiedenbeck, Phys. Rev. **70**, 435 (1946).
[2] R. B. Duffield and J. D. Knight, Phys. Rev. **76**, 573 (1949).

B9. Radiations from Long-Lived Tin Isotopes. J. W. MIHELICH AND R. D. HILL, *University of Illinois.**—The radiations produced in four samples of enriched Sn isotopes, which were activated by neutrons in the Oak Ridge pile, have been investigated using absorption and spectrographic techniques. Three hitherto unreported γ-ray transitions have been observed and their nature is at present being investigated. The energy values of the transitions and their assignments to particular Sn isotopes are given in Table I. No converted

TABLE I.

Isotope	Half-Life	γ-Transition
Sn^{117m}	14 days	159 and 162 kev
Sn^{119m}	≥ 100 days	69 kev
Sn^{123}	130 days	394 kev

γ-ray was detected in the 28-hr Sn^{121}. The 159-kev transition had been tentatively assigned to Xn^{119m}.[1] The conversion lines of the 69-kev transition are of very low intensity and an estimate for the activation cross section for the production of Sn^{119m} is ~0.02 barn. The 394-kev γ-transition associated with Sn^{123} probably follows the beta-ray activity and is converted in Sb.

* Assisted by the Joint Program of the ONR and AEC.
[1] M. Lindner and I. Perlman, unpublished. Reported by G. T. Seaborg and I. Perlman, Rev. Mod. Phys. **20**, 585 (1948).

B10. Disintegration of Sn^{125}.* ROBERT B. DUFFIELD, *University of Illinois*, AND LAWRENCE M. LANGER, *Indiana University.*—We have examined the beta- and gamma-rays emitted by the 9.5-minute Sn^{125} with a magnetic lens spectrometer. The radioactive sources used were prepared by neutron irradiation of tin metal foils enriched to 83 percent in Sn^{124}.[1] The source used for the determination of the beta-spectrum had a thickness of 6 milligrams per square centimeter. The beta-spectrum was found to be complex: There are two groups with end points at 2.04 and 1.17 Mev and a probable third group with an end point at 0.51 Mev. Conversion electrons from a gamma-ray of 0.326 Mev were found. The gamma-radiation was examined using uranium and lead radiators. Photo electrons from the 0.326-Mev gamma-ray were observed and also Compton electrons from one or more gamma-rays of energy greater than 1 Mev. The high energy gamma-radiation was of low intensity and the energy could not be accurately determined.

* Research done at the Los Alamos Scientific Laboratory of the University of California.
[1] Supplied by the Y-12 Plant, Carbide and Carbon Chemicals Corporation, on allocation by the Isotopes Division of the U. S. AEC.

B11. 14-Day Tin 117. E. C. MALLARY AND M. L. POOL, *The Ohio State University.*—The tin isotope which decays with a 14-day half-life by an isomeric transition is definitely assigned to mass number 117. By comparison of results of different bombardments of samples of electromagnetically enriched cadmium and tin, and by chemical separations, it was verified that the reactions $Cd^{114}(\alpha, n)$, $Sn^{116}(d, p)$, $Sn^{118}(n', 2n)$, $Sn^{117}(n', n)$, and $Cd^{116}(d, n)$, followed by decay to tin, produced this tin activity. By comparison of specific activities induced by the same neutron flux, the cross section of the reaction $Sn^{117}(n', n)$ was found to be about 1.8 times larger than the cross section of the reaction $Sn^{118}(n', 2n)$. Characteristic radiations are K and L conversion electrons of 0.146 ±0.006-Mev and 0.171±0.006-Mev energy respectively, tin

x-rays, and 0.175±0.006-Mev gamma-rays. These values were determined with a beta-ray spectrograph. By means of copper absorptions the *x*- and gamma-ray intensities from tin 117 were compared with those from indium 111. Indium 111, which decays with a 2.84-day half-life, is known to emit 1.72 gamma-rays to each *x*-ray. As a result of this comparison of *x*- and gamma-rays of comparable energies, it was found that the gamma-rays from tin 117 were about 50 percent internally converted.

B12. Disintegration of I^{124} and I^{126}. ALLAN C. G. MITCHELL, J. Y. MEI, FRED C. MAIENSCHEIN, AND CHARLES L. PEACOCK, *Indiana University.*—The nuclear radiations from I^{124} (4 days) and I^{126} (13 days) have been measured. I^{124} decays to Te^{124} with the emission of three positron groups with end points at 2.20±0.01, 1.50±0.01, and 0.67±0.05 Mev, possibly accompanied by some *K* electron capture. Gamma-rays of energy 0.603±0.002, 0.73±0.01, 1.72±0.02, and 1.95±0.05 are given off in the disintegration. I^{126} decays to Xe^{126} with the emission of two beta-ray groups of energies 1.268±0.010 and 0.085 ±0.01 Mev, together with a gamma-ray of energy 0.395 ±0.005 Mev. A metastable state of I, of 13.0±0.5 hours half-life, which decays under the emission of an internally converted gamma-ray of energy 0.159 Mev has been found. This metastable state is assigned to I^{124}. The high energy group of positrons from I^{124} has a forbidden shape of the type associated with $\Delta j = \pm 2$, first forbidden.

B13. Low Energy Beta-Ray Spectra: Pm^{147}, S^{35}.* H. C. PRICE, JR., J. MOTZ AND L. M. LANGER, *Indiana University.*—The beta-spectra of S^{35} and $_{61}Pm^{147}$ have been measured in an attempt to study further the nature of the low energy deviation from the Fermi theory previously reported.[1,2] Measurements were made with thinner sources and improved techniques in both the 40-cm radius of curvature spectrometer and also in a small 180 degree focusing Helmholtz coil spectrometer designed specifically for low energy spectra. The excess of particles at low energies was found to be a function of source thickness. The thinnest sources used were less than 10 micrograms/cm². Both S^{35} which is allowed and Pm^{147} which is probably once forbidden were found to have spectra of the allowed shape. Using counter windows of 3 micrograms/cm² and also a windowless counter technique, Fermi plots were obtained which, for Pm^{147}, were straight down to 8 kev. The end point of Pm^{147} was found to be 223.2±0.5 kev. On the basis of an improved calibration of the instrument, the present results for S^{35} yield an end point of 167.0±0.5 kev.

* Assisted by a grant from the Frederick Gardner Cottrell Fund of the Research Corp. and by the Joint Program of the ONR and AEC.
[1] Cook, Langer, and Price, Phys. Rev. **74**, 548 (1948).
[2] R. D. Albert and C. S. Wu, Phys. Rev. **74**, 847 (1948).

FRIDAY MORNING AT 10:45

Judd 126

(W. H. ZINN presiding)

Invited Papers on Neutron Physics

C1. The Use of Fast Neutrons for the Study of Nuclear Energy-Levels. H. H. BARSCHALL, *University of Wisconsin.* (30 min.)

C2. Resonance Neutron Scattering. C. O. MUEHLHOUSE, *Argonne National Laboratory.* (30 min.)

Invited Paper on Cryogenics

C3. Properties of Liquid Helium 3 and of Mixtures of Helium 3 and Helium 4. BERNARD ABRAHAM, *Argonne National Laboratory.* (30 min.)

FRIDAY MORNING AT 10:00

Mandel Hall

(J. G. WINANS presiding)

Contributed Papers on Electron-Emission

D1. X-Ray Absorption Factors for Coated Cylinders.* EUGENE B. HENSLEY, *University of Missouri.*—Absorption corrections for the calculation of Debye-Sherrer powder pattern diffraction intensities from a thin crystalline film of thickness *l* on a cylindrical absorbing base material have been computed using numerical methods. These are plotted as functions of μl at 10° intervals of the Bragg angle θ. Also computed over the same range are the corresponding absorption factors for x-rays diffracted from the underlying base material.

Possession of these correction curves affords a useful method for the measurement of the thickness of thin crystalline films on cylindrical wires.** This method is based on a comparison of the intensities of the diffracted lines from the surface material with the intensities of the lines from the underlying base material. The accuracy of the method has been checked using coatings of copper electroplated on nickel wires. An application of the method has been made in studying the growth in thickness of oxide cathode interfaces as a function of cathode life.

* This work was supported in part by the ONR.
** A. Eisenstein, J. App. Phys. **17**, 874 (1946).

D2. Luminescence of Barium Oxide.* VIRGIL L. STOUT, *University of Missouri.*—Studies of the luminescence spectra of BaO were made on active and inactive samples in the temperature range 340° to 575°K. Excitation was by means of electron bombardment of 3-Kev energy. The active sample was prepared by drawing a thermionic emission current from the heated oxide in the manner used for activation of oxide coated cathodes. The relative intensity distribution of the luminescence was recorded over the wave-length range 250 to 860 mμ. Several relatively strong luminescence bands were found from both active and inactive samples. The active material gave a luminescence band at 410 mμ which was not present from the inactive oxide. Similarly the inactive sample had a strong band at 460 mμ which appeared only weakly from the active sample. All luminescence bands did not exhibit the same temperature dependence.

* This work was supported in part by the ONR.

D3. Mass Spectrometric Production of Oxide Cathodes.* L. T. ALDRICH AND C. E. SMITH, *University of Missouri.*—A high intensity Nier-type mass spectrometer has been used as a source of pure BaO to coat a cathode of approximately 0.01 cm^2 area to thicknesses up to one monolayer. The thickness of the layer is monitored by continuously measuring the ion current to the cathode surface and assuming that all ions incident on the cathode are retained. Retarding potential measurements are used to measure the zero field, saturation emission current from the cathode. A pure nickel base cathode was produced in this manner. At a temperature of 1125°K, the thermionic emission is about 3×10^{-6} A/cm^2 for BaO layer of approximately one-half monolayer thickness. Cathodes produced using tungsten, molybdenum, and tantalum sleeves will be studied.

* This work was supported in part by the ONR.

D4. Extraction of Ions from Solids by Electrons in High Fields.* JEROME ROTHSTEIN, *Signal Corps Engineering Laboratories.*—Certain observations of Germer and Haworth[1] on anode pitting seem explainable only if electrons bombarding a metal surface in a high field can cause emission of positive ions with high yield. The voltages employed exceed positive ion thermionic work functions by at least several volts. Elastic transfer of energy from electron to surface atom can be neglected, leaving only inelastic transfer for consideration. In the absence of a high gradient at the surface a quantum would be emitted, or, alternatively, the excitation energy of the surface atom would appear as energy of thermal agitation, perhaps after wandering in the lattice as an exciton. Surface atom excitation is presumably accompanied by considerable increase in the effective atomic radius, and, in a high field, the strained binding between excited atom and lattice is broken with emission of a positive ion, the field overcoming image forces. The process is analogous to molecular dissociation under electronbombardment, with the metal a macromolecule, or to dissociation of excited atoms in high fields. From another viewpoint an excited atom is one of low effective ionization potential making the process analogous to formation of Cs^+ from Cs impacting on W. The sharp threshold voltage for the pitting process to be expected on this picture has been observed.

[1] L. H. Germer and F. E. Haworth, Phys. Rev. **73**, 1121 (1948).

Symposium of the Division of Electron Physics

Electron Emission

D5. Photoelectric Emission in Strong Fields: A Progress Report. A. H. WEBER, *St. Louis University.* (30 min.)

D6. Activity Studies on Pulsed Oxide Cathodes. E. A. COOMES, *University of Notre Dame.* (20 min.)

D7. The Leaky-Condenser Oxide-Cathode Interface. A. S. EISENSTEIN, *University of Missouri.* (30 min.)

FRIDAY AFTERNOON AT 2:15

Rosenwald Hall

(L. T. DEVORE presiding)

Symposium of the Division of Electron Physics

Gaseous Electronics

E1. The Glow-to-Arc Transition. J. G. WINANS, *University of Wisconsin.* (30 min.)

E2. A Double-Probe Method for Measurements in Steady and Time-Varying Gas Discharges. E. O. JOHNSON AND L. MALTER, *RCA Laboratories.* (35 min.)

E3. Electromagnetic Propagation in Ion Streams. L. R. WALKER, *Bell Telephone Laboratories.* (35 min.)

E4. Supersonic Wind at Low Pressures Produced by Magnetically Driven Arc. H. C. EARLY AND W. G. DOW, *University of Michigan.* (30 min.)

FRIDAY AFTERNOON AT 2:15

Mandel Hall

(F. W. LOOMIS presiding)

Invited Papers of General Interest

F1. The Origin of Terrestrial Magnetism. E. C. BULLARD, *University of Toronto.* (45 min.)

F2. High Speed Digital Computers: An Elementary Survey of Present Developments and Future Trends. L. A. RIDENOUR, *University of Illinois.* (45 min.)

Intermission: 10 min.

F3. Recent Developments in Cryogenics. J. G. DAUNT, *Ohio State University.* (60 min.)

FRIDAY AFTERNOON AT 2:15

Eckhart 133

(A. O. NIER presiding)

Optical Physics; Line-Spectroscopy; Nuclear Magnetic Resonance; Mass Spectrometry

G1. The Establishment of Mean Points of Transition Between Spectral Bands.* ZABOJ V. HARVALIK AND JOHN H. BOWEN,[1] *University of Arkansas.*—A method for obtaining the mean spectral band transition points is outlined and the mean values are presented. Comparison is made between transition values of this study and the values given in contemporary literature. The spectral transition points for binocular vision of light adapted eyes are: red, 739–613; orange, 613–597: yellow, 597–585; green, 585–517; blue, 517–479; violet, 479–422, at the brightness of the eyepiece slit of 0.002 foot candles/cm². The data were obtained from 125 individuals of the ages from 17 to 36 years of both sexes (42 women and 83 men). The selection of these subjects was made without selection with respect to eye deficiencies. Data on color ranges of monocular vision and binocular vision for the dark and light adapted eye are given.

* Based on work performed under contract with the Office of Chief of Ordnance, Department of Army.

[1] Ordark Research Fellow in Psychology.

G2. The Use of "Exploding Wires" as a Light-Source of Very High Intensity and Short Duration. WILLIAM M. CONN, *Rockhurst College.*—The flash of light obtained in discharging a large condenser through a very thin wire has been used as a light-source for obtaining high speed photographs and for making visual observations of rapidly moving objects. Copper wire was found most suitable for photographic exposures, while wires made of silver and chromel gave good results in visual work. Examples of some typical settings are presented using wires of silver, gold, aluminum, copper, steel, constantan, and chromel. Arrangements for increasing the intensity of single flashes of light and for multiple flashes are briefly discussed, as well as means for electrically exploding materials not available in the shape of thin wires.

G3. Forbidden $s-ns$ Lines in Alkali Metal Atomic Absorption Spectra. J. E. MACK, *University of Wisconsin.*—A re-examination of Kratz' long-path absorption spectrograms[1] shows that at least on the Rb plates there are, in addition to the series from the normal state to high d-, f-, g- . . . levels, transitions to s-levels in the neighborhood of 50s. These levels were overlooked before because they are only barely or partly resolved from those in the f series, where the asymptotic quantum defect is less by almost 3 units. The significance of their presence lies in their evidence that the unusual transitions must arise from disturbances attributable to other atoms, since the $0-0$ transition in 1 is strictly forbidden.

[1] H. R. Kratz and J. E. Mack, Phys. Rev. **76**, 193A (1949).

G4. Isotope Shift in the $2p\ ^1S_0-3s\ ^1P_1$ Line of Carbon.* JOHN R. HOLMES, *University of Southern California.*—A study has been made of appropriate methods of excitation of small samples of carbon in order to make a measurement of isotope shift in the atomic spectrum of carbon. It has been found that milligram amounts of carbon can be excited to give the 2479 A ($2p\ ^1S_0-3s\ ^1P_1$) line with good intensity and sharpness in a liquid nitrogen cooled electrodeless discharge tube of rectangular cross section, but that no other carbon lines appeared. The carrier gas was about 4 mm of helium but it is essential that it contain about 0.5 mm of oxygen to make the carbon line appear. Using a mixture of $C^{13}-C^{12}$ enriched to 52 percent C^{13}, a measurement of the isotope shift in this line was made with a Fabry-Perot interferometer crossed with a medium Hilger spectrograph. The normal mass effect, based simply on the change in the Rydberg constant, would predict an isotope shift in this line of plus 0.142 cm^{-1}. The observed shift, however, is minus 0.156 ± 0.002 cm^{-1}, indicating a "specific mass effect"[1] of minus 0.298 cm^{-1}.

* Supported by the ONR.

[1] D. S. Hughes and Carl Eckart, Phys. Rev. **36**, 694 (1930).

G5. Departure of the Lamb Shift from the n^{-3} Law in He^+. J. G. HIRSCHBERG, JR. AND J. E. MACK, *University of Wisconsin.**—Light of the Paschen line, λ4686, from a liquid-air-cooled hollow-cathode discharge was diffracted from a 21-foot grating, and the extreme violet portion ($3_{\frac{1}{2}}-4_{1\frac{1}{2}}$, in the notation n_j), isolated by a knife-edge, was subjected to a Fabry-Perot interferometric examination with several spacers ranging from 16 to 21 mm. The separation of the two[1] components, which (neglecting any p- and d-shifts) is just the 3s-shift, is between 0.116 and 0.128 cm^{-1}, and thus definitely smaller than

the 0.139 ± 0.003 which an n^{-3} extrapolation from the $2s$-shift[2] would yield. Other values to be compared, all based on the $3_{\frac{1}{2}}-4_{\frac{1}{2}}$ component and incorporating the assumption ($4s$-shift)/($3s$-shift)$=27/64$, are our previous tentative grating value[3] of 0.113 ± 0.014 cm^{-1} and Kopfermann's[4] 0.137 ± 0.015 and[5] 0.118 ± 0.003 cm^{-1}.

* Supported by contract with the ONR.
[1] J. E. Mack and N. Austern, Phys. Rev. **74**, 1262A (1948).
[2] M. Skinner and W. E. Lamb, Jr., Phys. Rev. **75**, 1325A (1949).
[3] J. E. Mack and N. Austern, Phys. Rev. **72**, 972 (1947).
[4] H. Kopfermann and W. Paul, Nature **162**, 33 (1948).
[5] H. Kopfermann, Zeits f. Physik manuscript sent to us in advance of publication.

G6. Hyperfine Structure and Isotope Shift in Barium. O. H. ARROE, *University of Wisconsin.**—Spectroscopic h.f.s. studies have been made with concentrated samples of the isotopes Ba^{137} and Ba^{135}.** The resonance lines of Ba II show that both isotopes have the spin 3/2 and that the splittings from Ba^{137} are 12 percent larger than those from Ba^{135}. A small isotope shift, in which the even isotopes are displaced with respect to the odd, is found in these lines. Earlier studies with natural barium have indicated the values 5/2 or 3/2 for both odd isotopes; the current acceptance of 3/2 has come from a consistency test by Hay,[1] who found by a molecular beam resonance method that the nuclear magnetic moments have the ratio $\mu_{137}/\mu_{135}=1.1174\pm0.0010$, although the structure of Ba^{135} had never been resolved from that of Ba^{137}. The disagreement among earlier investigations probably arose from the blending caused by the difference in the h.f.s. splittings of Ba^{137} and Ba^{135} (natural abundances respectively 11.32 and 6.59 percent).

* Supported by contract with the ONR.
** Produced by the Y-12 plant, Carbide and Carbon Chemicals Corporation, and obtained by allocation from the United States AEC.
[1] R. H. Jay, Phys. Rev. **60**, 75 (1941).

G7. Nuclear Moments of Mg^{25}. F. M. KELLY, A. L. SCHAWLOW, W. M. GRAY, AND M. F. CRAWFORD, *University of Toronto.*—The h.f.s. of the Mg I line 5167A ($3s3p\ ^3P_0-3s4s\ ^3S_1$) and the Mg II line 2796A ($3s\ ^2S_{1/2}-3p\ ^2P_{3/2}$), excited in an atomic beam source, have been resolved with a Fabry-Perot etalon. 5167A shows two faint components due to Mg^{25} at $+0.0303$ and -0.0341 cm^{-1}, and a Mg^{26} component at -0.0138 cm^{-1}, from the strong Mg^{24} component. If the Mg^{25} centroid is assumed midway between the Mg^{24} and Mg^{26} components, the interval rule gives $I=5/2$ and the inverted structure of $^3S_1$ shows that the magnetic moment is negative. The $^3S_1$ splitting gives $\mu(Mg^{25})=-0.97\pm0.05$ n.m. 2796A shows a strong Mg^{24} component and weaker Mg^{25} and Mg^{26} components $+0.0786$ and $+0.1021$ cm^{-1}, respectively, to higher frequencies. The intensity ratio between the Mg^{25} and Mg^{26} components confirms the negative moment and is consistent with $I=5/2$. Assuming that the Mg^{25} centroid is midway between the Mg^{24} and Mg^{26} components $\mu(Mg^{25})=-0.93\pm0.09$ n.m. The spin and the negative magnetic moment, but not its magnitude, agree with predictions for shell structure based on the individual particle model.

G8. The Effect of Electronic Paramagnetism on Nuclear Magnetic Resonance Frequencies in Metals.* W. D. KNIGHT,** *Brookhaven National Laboratory.*—Experiments have been performed[1] which show conclusively that nuclear magnetic resonance absorption in many metals occurs at frequencies which are appreciably higher than might be expected from the known nuclear g-values and the applied magnetic fields. This deviation in resonance frequency varies from 0.036 percent of the expected value in Li^7 to 1.20 percent in Pb^{207}. Measurements on Be^9, accurate to about ±0.002 percent, fail to disclose the existence of such a frequency shift. Assuming $g(I)$ to be invariant for a given isotope, one can describe the effect in terms of a paramagnetic contribution to the total magnetic field at the nucleus. To be sure, the volume susceptibility of most metals is too small (in many cases negative) to account for the effect. However, the average magnetic field at the nucleus will be greater than the average field in the volume of the metal if the conduction electrons, in addition to being paramagnetic, exist in states which allow them to spend appreciable time near the nucleus. The shift should be of the same order, then, as the hyperfine structure splittings of the corresponding atomic states. Quantitative agreement with experiment is obtained for Li^7 and Na^{23}. For Be^9, the absence of a measurable shift is justified.

* Work performed at Brookhaven National Laboratory under the auspices of the AEC.
** Permanent address: Trinity College, Hartford, Connecticut.
[1] W. D. Knight, Phys. Rev. **76**, 1259 (1949).

G9. Spin Echoes.* E. L. HAHN, *University of Illinois.*—A technique for obtaining nuclear resonance after the applied r-f field is turned off has been discovered. While the d.c. magnetic field is held at the resonance value the sample is subjected to two r-f pulses of high intensity, separated by time interval τ at pulse width $\ll\tau$. At time τ after the leading edge of the second r-f pulse a single spontaneous nuclear induction signal appears. This single echo is predicted by integrating the solution of Bloch's equation** of motion for a monochromatic spin group over all Larmor frequencies. The distribution of spins at thermal equilibrium over a range of Larmor frequencies imposed by magnetic field inhomogeneities provides a distribution in precessing spins grouped at frequency intervals of approximately $2\pi/\tau$ following the application of the twin r-f pulses. Measurements of the spin phase memory time T_2 for various substances agree with values obtained by conventional resonance methods. Advantages of the spin echo technique are (1) direct and accurate measurements of T_2, (2) elimination of balancing procedures in conventional resonance methods, (3) high signal to noise ratio, (4) higher stability and speed for hunting unknown resonances.

* Done under auspices of the ONR.
** F. Bloch, Phys. Rev. **70**, 460 (1946).

G10. Nuclear Quadrupole Effects in Solids. C. KIKUCHI, *Michigan State College.*—The discovery of the h.f.s. in solids by Penrose *et al.*[1,2] prompted us to consider the effects of the electric quadrupole moments of nuclei in crystalline solids. The quantum mechanical operators convenient for the calculation of this effect can be shown to be

$$(W_Q)_{\text{cryst}}=\tfrac{1}{6}(\partial^2 V_{\text{cryst}}/\partial z^2)_0[eQ/I(2I-1)](3I_z^2-I^2), \quad (1)$$

$$(W_Q)_{\text{electron}}=-\tfrac{1}{2}(e^2Q/I(2I-1))1/r^3[(3I\cdot r I\cdot r/r^2)-I^2]. \quad (2)$$

In the above, Eqs. (1) and (2) are due to the crystalline and the electron electric fields respectively. Polder's model of copper sulfate crystal was used in carrying through our provisional calculations. The effects of strong and weak magnetic fields were investigated.

[1] Penrose, Abragam, and Pryce, Nature **163**, 922 (1949).
[2] Bleaney, Ingram, and Pryce, Nature **164**, 116 (1949).

G11. Retardation of High Velocity Ions in Gases. A. J. DEMPSTER AND A. E. SHAW, *Argonne National Laboratory.*—In connection with the measurement of the masses of isotopes with a double focusing mass spectrograph using 8000-volt ions, it was observed that differences in the spacing of narrow doublets occur when small amounts of gas are present. The differences are no doubt due to different retardations of the ions in the residual gas, and from the doublet changes it is possible to deduce the energy losses, even when they are only 2 parts in 100,000 or 0.16 volt in the 8000 used. At pressures of 10^{-5} mm the singly charged NO^+ ion was retarded 1.05 volts more than the doubly charged nickel ions. At higher pressures when benzene was introduced to give comparison lines, energy losses in Sm^{+2} and Sm^{+3} ions were as much as 16 volts more

than in the corresponding hydrocarbon ions. With quadruply charged samarium ions an unexpected phenomenon was observed—two ionic types of the Sm^{+4} isotopes are formed. One suffers very large energy losses compared with the other, up to 58 volts, and is strongly scattered, while the second type of Sm^{+4} isotopes remain as sharp as at low pressure.

G12. A Simplified Emission Regulator for Mass Spectrometer Ion Sources. E. B. WINN AND ALFRED O. NIER, *University of Minnesota.*—A simplified electron emission regulator has been developed which operates by controlling the space current instead of the filament heater current. Regulation is accomplished by the insertion of a control plate between the filament and the shield. The control plate is connected to the filament through a biasing battery and control resistor, through which the emission current is allowed to pass. In spite of the fact that no vacuum tubes are required in this circuit, the regulation characteristics are essentially the same as those of the electronic devices previously used.[1]

[1] Alfred O. Nier, Rev. Sci. Inst. **18**, 398 (1947).

G13. Atomic Mass Determinations with a Mass Spectrometer.* T. R. ROBERTS AND ALFRED O. NIER, *University of Minnesota.*—The double focusing mass spectrometer previously described[1] has been employed to measure the mass doublets H_2-D, $C^{12}H_2-N^{14}$, $C^{12}H_4-O^{16}$, $H_2O^{16}-A^{36}/2$, $C_3^{12}H_4-A^{40}$. The mass differences in 10^{-4} a.m.u. were found to be 15.49, 126.1, 364.5, 267.7, and 688.5, respectively. Although the internal consistency was such as to indicate a p.e. of a few parts in 10^6 of the ion mass number measured, the results on the first three are all about 5 parts per 10^6 higher than those compiled by Bainbridge.[2] The measurement on H_2-D supports the results from recent disintegration experiments;[3,4] however, the existence of an undiscovered systematic error of the magnitude suggested above would put the doublet in direct agreement with that of Mattauch and Bonisch.[5]

* Supported by Joint Program of the AEC and the ONR.
[1] Nier, Roberts, and Franklin, Phys. Rev. **75**, 346 (1949).
[2] K. T. Bainbridge, National Research Council Preliminary Report No. 1, Nuclear Science Series, 1948.
[3] R. F. Taschek *et al.*, Phys. Rev. **75**, 1268 (1949).
[4] A. V. Tollestrup *et al.*, Phys. Rev. **75**, 1947 (1949).
[5] J. Mattauch, Phys. Rev. **57**, 1155 (1940).

FRIDAY AFTERNOON AT 2:15

Kent Theatre

(I. I. RABI presiding)

Artificial Radioactive Substances; Radioactivity of Neutron; Capture and Scattering of Neutrons

H1. 9.0-Minute La^{136}. B. E. ROBERTSON, W. L. CARSS, AND M. L. POOL, *The Ohio State University.*—The 9.0 ± 0.5-minute activity[1] in lanthanum is assigned to mass number 136. This activity was produced in the lanthanum fraction when Hilger CsCl was bombarded with 20-Mev alpha-particles and is ascribed to the reaction $Cs^{133}(\alpha, n)$. Barium samples, electromagnetically enriched in Ba^{134}, Ba^{135}, and Ba^{136}, respectively, when bombarded with 10-Mev deuterons, produced the 9-minute lanthanum activity with relative yields in agreement with the above mass assignment, the reactions being $Ba^{135}(d, n)$ and $Ba^{136}(d, 2n)$. Characteristic radiations are positrons, x-rays, and gamma-rays. The maximum energy of the positrons is 1.8 ± 0.1 Mev as obtained by aluminum-absorption measurements.

[1] W. Maurer, Zeits. f. Naturforschung **2a**, 586 (1947).

H2. Beta-Spectrum of Pr^{143}.* J. BRUNER,** L. M. LANGER, AND D. MOFFAT, *Indiana University.*—The beta-spectrum of Pr^{143} (13.8*d*) has been studied in the 40-cm radius of curvature-shaped magnetic field spectrometer and also in a smaller version employing a 15-cm radius of curvature. Although the comparative half-life ($ft \sim 4.5\times10^7$) indicates that the transition is once forbidden, the spectrum was found to have the allowed shape. This suggests that the spin change must be less than 2. In order to satisfy these conditions it is necessary that, in this case, the $2d_{5/2}$ and $1g_{7/2}$ states be inverted in the nuclear shell model of M. G. Mayer.[1] The end point was found to be 0.922 ± 0.003 Mev.

* Assisted by a grant from the Frederick Gardner Cottrell Fund of the Research Corporation and by the Joint Program of the ONR and AEC.
** AEC Fellow.
[1] M. G. Mayer, Phys. Rev. **75**, 1969 (1949).

H3. $\beta-\gamma$ Angular Correlation in Au^{198} and Rb^{86}. SHERMAN FRANKEL, *University of Illinois.**—$\beta-\gamma$ angular correlations have been investigated using scintillation counter detectors. The angular correlation in Au^{198} was found to be isotropic from $\frac{3}{8}\pi$ to π ($R/Q=1.00\pm0.01$). This is in agreement with an allowed shape for the beta-spectrum. The isotropy was unaltered by biasing the beta-detector to accept only the upper 10 percent of the beta-spectrum. Using Rb^{86}, from which Cs^{134} impurities were removed with an ion-exchange column, the correlation coefficient for the $\beta-\gamma$-branch was determined as -0.094 ± 0.015. This coefficient is consistent with either of two theoretical coefficients, both requiring the interaction to be Gamow-Teller, first forbidden, ($L=2$). The coefficient leading to a spin of 2 for Rb^{86} is consistent with the shape of the spectrum of the direct beta-transition to Sr^{86}, the empirical lifetime, and the parity of Rb^{86} as obtained from the nuclear shell model. It requires a spin of 2 for the excited state in Sr^{86} and specifies the γ-radiation as electric quadrupole.

* Assisted by the Joint Program of the ONR and the AEC.

H4. Investigation of Momentum Relations in the Decay of Be^7. PHILIP B. SMITH AND JAMES S. ALLEN, *University of Illinois.*—In the 90 percent branch of the decay of Be^7 through orbital electron capture to the ground state of Li^7, the excess energy is carried away by the neutrino, according to the usual neutrino hypothesis. Accordingly the Li^7 recoil nucleus must have a well-defined momentum. A highly concentrated source of Be^7 has been deposited as a thin film by successive evaporation. Using an electron multiplier tube and a retarding potential method, the energy distribution of the Li^7 recoils has been studied. Due to energy losses in the source a spectrum of energies appeared. The maximum energy of the recoils has been found to be 56.6 ± 1.0 ev. This is to be compared with the expected value of 57.3 ev predicted from the known Be^7-Li^7 mass difference. In addition we have made time-of-flight measurements on the 10 percent branch of the decay in which a γ-ray is emitted. The γ-ray is used to trigger a sweep and the time-of-flight spectrum of the recoils is displayed on

a CRT. Preliminary results indicate the presence of recoils of the expected energy. Auger electrons of approximately the expected energy of 35 ev have also been observed with the electron multiplier.

H5. Excited States of Be^7. J. C. GROSSKREUTZ AND K. B. MATHER,* *Washington University.*—Evidence for the existence of excited states of Be^7 below 1 Mev has been found from a study of the neutrons produced in the reaction $Li^7(p, n)Be^7$. Using a beam of homogeneous protons of 5-Mev energy from the Washington University cyclotron, the neutrons were detected by a standard photographic plate method. In addition to the ground state group of neutrons, three additional lower energy groups were observed indicating a level structure for Be^7. Three separate runs on three separate targets of varying thickness gave the same results. Observations were made at 20° and 90° to the proton beam for each target. In every case the shift in energy of the peaks as one goes from 90° to 20° is consistent with the assignment of definite levels to Be^7. Values obtained for the excitation energies are: 0.205 ± 0.070 Mev, 0.470 ± 0.070 Mev, and 0.745 ± 0.070 Mev above the ground state. The level at 470 kev is analogous to the well-known level at 478 kev in the mirror nucleus Li^7. The other two levels have no correspondence as yet observed in Li^7. Q for the ground state reaction was found to be -1.65 ± 0.04 Mev in good agreement with previously obtained values.

* Assisted by the Joint Program of the ONR and the AEC.

H6. Radioactive Decay of the Neutron. J. M. ROBSON, *Chalk River Laboratory.*—The positive particle from the radioactive decay of the neutron has been identified as a proton from a measurement of charge to mass. A collimated beam of neutrons emerging from the Chalk River pile passes between two electrodes in an evacuated tank. One electrode is held at a positive potential, up to 20 kev, while the other electrode is grounded and forms the entrance aperture to a thin lens magnetic spectrometer, the axis of which is perpendicular to the beam of neutrons. The positive decay particles can be focused on the first electrode of an electron multiplier. The background counting rate is 60 c.p.m. A peak of 80 c.p.m. is observed above background when the magnetic field is adjusted for protons of energy expected from the electrostatic field. When a thin boron shutter is placed in the neutron beam, the proton peak disappears. Preliminary estimates of the collecting and focusing efficiency and the neutron flux indicate a minimum half-life of 9 minutes and a maximum of 18 minutes for the neutron.

H7. Thermal-Neutron Capture Cross Sections of Sixty Eight Elements. H. POMERANCE, *Oak Ridge National Laboratory.*—The Oak Ridge pile oscillator, previously described,* has been used for a uniform survey of the thermal neutron capture cross sections of the elements. Sixty eight elements from atomic number 3 to 82, nine of them not previously measured, have been measured by comparison with gold. The capture cross section of gold is known from other work. From the internal consistency of the measurements, the care in selecting samples, and the accuracy of the value for gold, a precision of 5 percent is estimated. A comparison will be given with the results of other methods such as time-of-flight and activation.

* J. I. Hoover *et al.*, Phys. Rev. **74**, 864 (1948).

H8. Total Fast Neutron Cross Section of Potassium. R. E. PETERSON, *University of Wisconsin.*—The total neutron cross section of potassium has been measured for neutron energies ranging from 15 to 600 kev. The cross section was obtained by transmission measurements, using a neutron energy spread of 15 kev. Maxima in the cross section were found for neutron energies of 70, 110, 160, 305, 360, 430, 490, and 560 kev. The largest cross section observed was about 3.7 barns, at 70 and 305-kev neutron energy, while in the region between maxima, the cross section was less than 2 barns. It is interesting to note that for both potassium and calcium,[1] whose most abundant isotopes contain "closed shells"[2] of twenty neutrons, the total neutron cross section between maxima is considerably smaller than that of other nuclei in this region of the periodic table.

* This work was supported in part by the AEC and in part by the Wisconsin Alumni Research Foundation.
[1] Adair, Barschall, Bockelman, and Sala, Phys. Rev. **75**, 1124 (1949).
[2] M. G. Mayer, Phys. Rev. **74**, 235 (1948).

H9. Dependence of Neutron Cross Sections on Mass Number.* R. K. ADAIR,** *University of Wisconsin.*—The total neutron cross sections of Ti, Zn, Cu, Sn, and W have been measured for energies from 50 to 1400 kev, using a neutron energy spread of about 100 kev. The cross sections were determined by means of simple transmission measurements as previously described.[1] The neutron energy spread is assumed to be large enough compared to the average spacing between energy levels, so that the values represent an average over many resonances and can be compared to the predictions of statistical theories.[2] The results show the anomalous variation of cross sections with mass number which was noticeable in previous work.[1,3] The cross sections of Ti, Zn, Cu, and W reach their highest values at the lowest neutron energies and decrease with increasing neutron energy. The cross section of Sn, in common with other elements of mass number near 100, is almost independent of neutron energy.

* This work was supported in part by the AEC and in part by the Wisconsin Alumni Research Foundation.
** AEC Predoctoral Fellow.
[1] Bockelman, Peterson, Adair, and Barschall, Phys. Rev. **76**, 277 (1949).
[2] Feshbach, Peaslee, and Weisskopf, Phys. Rev. **71**, 145 (1947).
[3] Barschall, Bockelman, and Seagondollar, Phys. Rev. **73**, 659 (1948).

H10. Total Cross Sections of C, O, Mg, Si, and S for Neutrons in the Energy Range 0.6 Mev to 1.8 Mev.* GEO. D. FREIER, E. E. LAMPI, AND J. H. WILLIAMS, *University of Minnesota.*—The fast neutron total cross sections of light nuclei which may be considered to consist of an integral number of alpha-particles were determined by measuring the transmission of disks of C, Mg, Si, S, and SiO_2. The thickness of each scatterer was adjusted so that the average transmission was about 50 percent. By using the $Li^7(p, n)Be^7$ reaction as a source of neutrons with a 30-kev thick Li target source the neutrons were sufficiently monoergic to resolve apparently most of the excited levels of the compound nucleus when bombarded with neutrons in the energy range 0.6 Mev to 1.8 Mev. A pulse ionization chamber with a paraffin radiator was used as a detector and was placed at 0 degrees with respect to the incident proton beam where the neutron energy varied only a fraction of a percent in the solid angle subtended by the detector. All elements except C showed a rather complex set of resonance levels in the above energy range and the complexity increased with atomic number. Enough counts were taken to make the probable errors in the measurements ±5 percent. The data will be presented in the form of curves showing total cross section as a function of incident neutron energy.

* This research was supported in part by the ONR.

H11. Total Neutron Scattering Cross Section of Helium.* S. BASHKIN, B. PETREE, F. P. MOORING, AND R. E. PETERSON, *University of Wisconsin.*—The total cross section of helium for fast neutrons has been determined by comparing the transmission of a thin-walled cylinder filled with 8000 p.s.i. of helium with that of an identical, empty cylinder. Neutrons were obtained from the $Li(p, n)$ and $d-d$ reactions and were detected by a hydrogen recoil counter. Measurements were carried out under conditions of good geometry for neutrons of energies between 40 kev and 6.4 Mev. The helium cross section increases smoothly from 0.8 barn at 40 kev to 6.7 barns at

1.1 Mev, and then decreases to 2.3 barns at 6.4 Mev, the statistical uncertainty being 0.1 barn. From 0.95 Mev to 1.32 Mev, measurements were taken in 30-kev steps with a neutron energy spread of 30 kev. No evidence was found for the two maxima reported by Staub and Tatel.[1] As a check on the present helium measurements, the hydrogen cross section was determined at 1 Mev by the same method. The value of 4.2 ± 0.1 barns agrees with the results of Lampi *et al.*[2]

* This work was supported in part by the AEC and in part by the Wisconsin Alumni Research Foundation.

[1] H. Staub and H. Tatel, Phys. Rev. **58**, 820 (1940).
[2] Lampi, Freier, and Williams, Phys. Rev. **76**, 188 (1949).

H12. Neutron Scattering in the Resonance Region. J. TITTMAN, C. SHEER, J. RAINWATER, AND W. W. HAVENS, *Columbia University.*—The Columbia neutron velocity spectrometer,[1] hitherto used only for transmission experiments, has been applied to the direct measurement of neutron scattering in the 1–100-ev region. The neutron beam is collimated by a 3-inch square tube lined with small bricks made of B_4C. It then enters a large chamber similarly lined. The scattering target, located near the center of the chamber, is placed with its front face at 45° to the beam. The neutrons scattered in the general direction perpendicular to the beam leave the scattering chamber through a 1-foot square port and are detected by twenty BF_3 counters in parallel. The counter pulses are fed into the velocity selector. The total path of the scattered neutrons, consisting of the distance from the paraffin source slab to the scattering target plus the distance from the scattering target to the BF_3 counters is known. Since the velocity selector sorts the neutron pulses fed to it according to the time of flight over the known path, the energy distribution of the scattered neutrons is determined. Results on resonance and potential scattering will be presented.

[1] J. Rainwater and W. W. Havens, Jr., Phys. Rev. **70**, 136, 154 (1946).

H13. Interaction of 12–13-Mev Neutrons with Deuterons. G. L. GRIFFITH, M. E. REMLEY, AND P. G. KRUGER, *University of Illinois.*—12–13-Mev neutrons produced by bombarding a thin deuterium gas target with 10-Mev deuterons have been scattered from deuterons in a high pressure cloud chamber filled with CD_4. 4229 tracks with the appropriate lengths to be deuteron recoils were observed between 0° and 70° in the laboratory system. A small percentage of these tracks were due to a 3 percent contamination of ordinary hydrogen, and the remainder were recoil deuterons or protons from the $d(n, 2n)p$ reaction. That this reaction exists was evident by the presence of tracks between 60° and 90° in the laboratory system which were too long to be accounted for by either deuteron or proton recoils. Because of lack of sufficient information at this time no correction on the $n-d$ scattering angular distribution has been made for this reaction. The angular distribution of observed tracks shows a minimum at 60° for the center of mass recoil angle with a forward peak 6.5 times as large as the minimum and rises to 4.5 times minimum at 130° and 20°.

FRIDAY AFTERNOON AT 2:15

Breasted Hall

(A. W. LAWSON presiding)

Solid-State Physics

J1. Thermoluminescence of Calcium Sulfate: Mn Phosphor. K. WATANABE, *Naval Research Laboratory.*—As part of the program on upper atmosphere research, observations* of extreme ultraviolet and x-rays from the sun were recently made with thermoluminescent calcium sulfate: Mn phosphors mounted on V-2 rockets. To permit their use as detectors of radiation it was necessary to establish several properties. The sensitivity was found to commence at 1300A, as reported by Lyman, and extended to x-rays and gamma-rays. The phosphor was excited conveniently by radiation between 1100 and 1300A produced by a hydrogen discharge tube with LiF window. The thermoluminescence extended from 4480 to 5790A with the maximum at 5020A. The sensitivity was constant for exposure temperatures from 80°C to at least −40°C. Near 25°C the emission was proportional to $1/t$ and to the total initially stored energy. The stored energy was reduced by near ultraviolet but was not affected by infra-red or visible. The stored energy was a function of tI and was directly proportional until saturation set in. The total thermoluminescence was independent of the heating cycle.

* Purcell, Tousey, and Watanabe, Phys. Rev. **76**, 165 (1949).

J2. Diffraction Effects Observed in Partially Ordered CoPT Crystals. JOHN B. NEWKIRK AND R. SMOLUCHOWSKI, *Carnegie Institute of Technology.*—A detailed x-ray study of single crystals of CoPt at early stages of the ordering process shows the presence of lattice aperiodicities in some of the [110] directions. This is demonstrated by the presence of [110] rods in the reciprocal lattice which run through matrix points. It is found that different rods of the ⟨110⟩ family are missing at different matrix points. This is interpreted to indicate that the aperiodicities have their origin in the strains which accompany the transformation from disordered cubic to the ordered tetragonal phase, rather than in the presence of platelets of different concentration. It is proposed to correlate these internal strains with the high coercive force which this alloy exhibits when at an intermediate state of order, as predicted by Becker's theory.

J3. Electronic Band Structure in Disordered Alloys.* HUBERT M. JAMES AND ARTHUR S. GINZBARG,** *Purdue University.*—Disordered alloys and crystals with randomly distributed substitutional impurities resemble pure crystals in the regular arrangement of crystal cells, but differ in the random distribution of atoms into cells. To investigate the applicability of the idea of electronic band structure to these non-periodic systems, an equivalent one-dimensional wave equation has been studied, in which the potential energy in successive cells of length is randomly assigned one of two forms, A and B, with probabilities p_a and p_b. The number of states $N(E)$ below energy E is proportional to the average number of nodes per cell of any solution, and the energy density of states is obtained as dN/dE. One can reduce the problem of determining the average number of nodes per cell to that of solving a functional equation for the distribution of initial phases in the cells, or can count the nodes in a long sequence of randomly chosen cells. Illustrative calculations show the gradual washing out of the original band structure

of the pure type A crystal, and the spreading out of "impurity states" to form a diffuse impurity band, as the "impurity" density (p_b) is increased.

* Work partially supported by Signal Corps contract.
** Present address: Shell Oil Company, Houston, Texas.

J4. The Energy Absorbed in Twinning Single Crystals of Zinc.* EDWARD I. SALKOVITZ AND JAMES S. KOEHLER, *Carnegie Institute of Technology.*—The energy absorbed in producing twins in single crystals of zinc by means of ballistic impacts has been measured in the manner first described by B. Chalmers. Chalmers found an absorption of 0.8×10^6 erg/cc of twin for single crystals of tin. Data on 14 specimens indicate that zinc behaves differently from tin. It was found necessary to deform the zinc crystals plastically before twinning could be produced. Seven one-inch specimens, cut from three different crystals with (001) pole at 83° with the specimen axis, required, on absorption, of from 0.71×10^6 to 1.33×10^6 erg/cc of sample before twinning. Subsequent twinning occurred with an absorption of 0.45 to 4.6×10^6 erg/cc of twin. Five one-inch specimens, cut from the same crystal whose orientation was 80°, absorbed between 0.21×10^6 and 0.59×10^6 erg/cc of sample before twinning. An additional absorption of between 0.21×10^6 and 1.48×10^6 erg/cc of twin was required for the production of twins. Two specimens cut from the same 75° crystal required 0.50×10^6 and 0.56×10^6 erg/cc of sample before twinning. Subsequent twinning occurred with an absorption of 0.92×10^6 and 2.07×10^6 erg/cc of twin. In the latter specimen severe bending occurred. In general the "fore" energy and the "twinning" energy depend on the kinetic energy of the striker at the moment of impact.

* This work was supported by ONR contract.

J5. Revised Procedure for Measuring Internal Friction.* J. S. KOEHLER AND J. W. MARX, *Carnegie Institute of Technology.*—The use of an auxiliary piezoelectric gauge in conjunction with an a.c. bridge as a means of measuring both strain amplitudes and decrement over wide ranges is described. Consistent and reproducible decrement values varying from 10^{-6} to 10^{-2}, measured over strain amplitudes of from 10^{-8} to 10^{-4}, have been obtained for single crystals of copper, lead, and quartz, using the improved technique. A previously established method of decrement measurement with the a.c. bridge alone, involving the determination of the width of the resonance peak, which has been extensively employed by T. A. Read and others, including the authors, is shown to be invalid for those cases in which the a.c. resistance varies appreciably with the strain amplitude. Comparison of data obtained on the same specimens by the two procedures shows excellent agreement for quartz samples, for which the decrement is virtually independent of the strain amplitude, but a very marked disagreement exists for copper and lead specimens, particularly at high strain amplitudes. In the latter case, decrement calculated by the resonance peak width method is frequently more than ten times as great as that calculated by the revised procedure. A supplementary calculation, involving piezoelectric relationships, has been devised which permits the salvage of data previously calculated by the resonance peak width method over regions in which the latter is not applicable.

* This research was sponsored by the ONR.

J6. Effects of Etching, Annealing, and Threshold Deformation on the Internal Friction of Copper.* J. W. MARX AND D. A. PATTERSON, *Carnegie Institute of Technology.*—(1) Unannealed and annealed copper single crystals were first weighed, then cemented to quartz driver-gauge combinations and piezoelectrically driven at their fundamental frequency of 37 kc at a constant strain amplitude of 5×10^{-7}. The cylindrical surfaces of the rod shaped specimens were etched away by periodic immersion in nitric acid, with the loss in mass of about two percent per etch determined by chemical analysi of the etchant. After each etch the decrement in vacuum wa measured and plotted against the decreasing mass. Unannealed crystals showed *decreases* of as much as 50 percent in decrement with a loss of less than five percent in mass, but annealed specimens without exception exhibited marked *increases* in decrement following the first few etches. (2) The decrement of copper single crystals was first measured at a reference strain amplitude of about 5×10^{-7}, after which the vibrational amplitude of the composite resonator at resonance was raised from this value to a maximum working strain of about 5×10^{-5} in a series of small steps. After each increment in working strain the reference level strain was restored and the decrement remeasured. The first change in the reference level decrement was a slight increase occurring after applications of working strain amplitudes of about 1×10^{-5}, while very pronounced increases were observed following larger working strains.

* This research was sponsored by the ONR.

J7. Internal Friction of Metals at Very High Temperatures. T'ING-SUI KÊ, *University of Chicago.*—In connection with the study of the internal friction peak (*versus* temperature) associated with the viscous behavior of grain boundaries in metals, some other effects were observed at higher temperatures causing an additional internal friction in superposition with the high temperature branch of this internal friction peak. This additional internal friction was found to have its origins in some effects of cold-working introduced in the interior of the grains which remain even after the complete recrystallization of the specimen. It increases with the amount of cold-work the specimen was subjected to before and after recrystallization; it decreases with annealing at successively higher temperatures until a stable value is reached; and it increases with the precipitated impurity content in the specimen. This high temperature internal friction is very high in an aged specimen of 99.991 aluminum alloyed with four percent copper. These observations are consistent with the viewpoint that this internal friction is caused by the presence of dislocations in the interior of the specimen although the mechanism of giving rise to the internal friction is unknown. It is pointed out that a study of high temperature creep under very low stress may be conveniently carried out through the internal friction measurements described.

J8. The Creep of Pure Copper and Lead Single Crystals.* PETER W. NEURATH AND J. S. KOEHLER, *Carnegie Institute of Technology.*—Single crystals of 99.999 percent purity were grown by the Bridgman method in the form of standard tensile specimens of one-inch gauge length. The strains range from 10^{-5} to 10^{-2}. Measurements were made at 90°K and 295°K. Loads are applied by sliding a weight along a lever using a motor drive. The applied stress is increased by small increments (10 g/mm² for Pb). Below the yield stress such an increment results in a transient increment of strain which is less than 10^{-4}; however the first increment which exceeds the critical stress results in a transient strain of about 10^{-3} which occurs in less than five minutes. The yield stress did not depend on the temperature for copper and lead. For lead the yield stress is 100 g/mm²±10 g/mm²; for copper it is 300 g/mm². Steady-state creep was observed in lead for periods up to 1000 minutes, the steady-state rate decreases with decreasing temperature. For example at a stress of 150 g/mm² the transient creep is still less than 10^{-2}; the steady-state rate is 10^{-4} per minute at 295°K whereas it is only 1×10^{-6} per minute at 90°K. The rates mentioned in the example are the extreme rates measurable. Changing the orientation, annealing the copper, and adding 0.0015 percent Bi to the lead did not influence the behavior.

* This research supported in part by NACA contract and by ONR contract.

J9. Measurement of the Activation Energy for Motion of Dislocations in Single Crystals of Copper. A. S. NOWICK, *Columbia University.*—Measurements of internal friction were made on single crystal rods of copper in forced longitudinal vibration. The method was that of Read[1] extended by positioning the composite oscillator in a cryostat which permitted temperature variation between +30°C and −60°C, and by the use of a liquid adhesive which prevented strain of the specimen due to differential thermal expansion at the quartz-specimen interface. The variation of decrement with strain amplitude at constant temperature was observed to decrease with decreasing temperature proportionately to $\exp(-\epsilon/kT)$. It has been shown[1] that in single crystals of copper, amplitude-dependent internal friction results from the motion of dislocaalready present in the crystal lattice. Therefore, it was concluded that the observed values of ϵ correspond to the activation energy for such motion. Values of ϵ were obtained for two crystals initially annealed in vacuum and subsequently subjected to static compressional stress which introduced a definite amount of cold work. The results were 1300 and 1600 cal./mole, the second representing the more highly worked crystal.

[1] T. A. Read, Phys. Rev. **58**, 371 (1940); Trans. A.I.M.E. **143**, 30 (1941).

J10. Growth of Alkali Halide Crystals from the Vapor Phase onto Substrates of Mica. L. G. SCHULZ, *University of Chicago.*—Thin films of alkali halides were formed by evaporation in a vacuum on mica substrates and studied by means of electron diffraction. It was found that the crystals of all substances had a [111] direction normal to the substrate. In addition there was an angular orientation about this direction which depended on the lattice constant, a_0, in the following way: (1) when a_0 was larger than 5.36A (a_0 for KF) the angular orientation of the hexagonal net of atoms in the deposit at the interface matched exactly the orientation of the network of potassium atoms in the cleavage face of mica. (2) For LiCl (a_0 equal to 5.14A) the angular orientation was random but the [111] fiber structure was well defined. (3) NaF (a_0 equal to 4.62A) had a definite [111] fiber structure but was mixed with a large component of crystals having random orientation. (4) For LiF (a_0 equal to 4.02A) the hexagonal network at the interface was turned 30° in respect to the potassium atom network of the substrate. By considering the crystal structure of mica an attempt is made to explain the observed orientation of each substance.

J11. Magnetic Properties of Zinc Alloys at Low Temperatures. JULES A. MARCUS,* *Northwestern University.*—The de Haas-van Alphen effect and the temperature dependence of susceptibility have been investigated for pure zinc and zinc alloyed with small amounts of copper and aluminum. Measurements were made on single crystals by the Faraday method in fields ranging from 2.5 to 11 kilogauss and temperatures down to 14°K. The addition of copper (up to 0.32 atomic percent) to New Jersey super-pure zinc shifted the d.H.-v.A. oscillations to higher fields, increased their frequency, increased the amplitude of the high field oscillations, and decreased the amplitude at low fields. The addition of aluminum (up to 0.26 atomic percent) decreased the frequency of the oscillations by an amount comparable with the experimental error while the amplitude decreased markedly for all field strengths. The temperature dependence of susceptibility was investigated at temperatures above that at which the d.H.-v.A. effect becomes negligible. The anomalous maxima and minima characteristic of the susceptibility parallel to the hexagonal axis of pure zinc were found in all the alloys. For the copper alloys, the extremes were less pronounced and shifted to slightly higher temperatures. For the aluminum alloys, the mean value of susceptibility decreased but the temperature dependence curves were otherwise identical with those for pure zinc.

* This work was carried out while I was a Union Carbide and Carbon Postdoctoral Fellow at The Institute for the Study of Metals, University of Chicago.

J12. Paramagnetic Anisotropy of Manganous Fluoride. J. W. STOUT AND MAURICE GRIFFEL, *University of Chicago.*—The magnetic anisotropy of single crystals of MnF_2 has been measured over the temperature range 12 to 300°K. The measurements were made with a torsion balance. Temperature control was obtained with baths of hydrogen, nitrogen, oxygen, and ethane boiling under regulated pressure. At temperatures above 100°K the anisotropy is of the order of 0.1 percent of the susceptibility, and the greater susceptibility is in the direction of the c-axis of the tetragonal crystal. Below 70°K the anisotropy becomes extraordinarily large and the susceptibility in the direction of the c-axis is smaller than that perpendicular to the c-axis. Previous investigators have found a maximum in the powder susceptibility and in the heat capacity in the neighborhood of 70°K. Combining the present measurements with those of the powder susceptibility, the directional susceptibilities parallel and perpendicular to the c-axis can be calculated. The parallel susceptibility approaches zero at zero temperature and the perpendicular susceptibility increases by about 12 percent as the temperature drops from 70°K to 14°K. These results will be discussed in connection with the theory of antiferromagnetism proposed by Van Vleck.

[1] J. H. Van Vleck, J. Chem. Phys. **9**, 85 (1941).

FRIDAY EVENING AT 7:00

Shoreland Hotel

(F. W. LOOMIS presiding)

Banquet of the American Physical Society

After dinner talks by S. K. ALLISON AND E. C. BULLARD.

SATURDAY MORNING AT 9:45

Kent Theatre

(W. SHOCKLEY presiding)

Invited Papers in Solid-State Physics

L1. Optical Behavior of Semiconductors. H. Y. FAN, *Purdue University.* (40 min.)

L2. "Drift Mobility" and Lifetimes of Injected Electrons and Holes in Germanium. J. R. HAYNES, *Bell Telephone Laboratories.* (40 min.)

L3. Neutron Diffraction and Magnetic Crystallography. C. G. SHULL, *Oak Ridge National Laboratory.* (40 min.)

L4. Fundamental Mechanisms of Diffusion in Metals. J. H. HOLLOMON, *General Electric Company.* (30 min.)

SATURDAY MORNING AT 10:00

Mandel Hall

(L. W. ALVAREZ presiding)

Cosmic Rays and Artificial Mesons

M1. Neutron Production in Elements at High Altitudes.* J. A. SIMPSON, H. W. BALDWIN,† AND S. MOLNER, *University of Chicago.*—Measurements of the local production of fast neutrons from C, Al, Cu, Sn, and Pb have been made at altitudes of 30,000 and 35,000 feet pressure altitude using large paraffin neutron moderator geometries in aircraft during the past year and a half. Between 40° and 55°N magnetic latitude the local production from lead showed a factor of increase of 1.4 to 1.5 corresponding to the increase for the measured production of nuclear disintegrations and neutrons in the atmosphere.[1] An estimate of the absorption in lead for the incident neutron producing radiation of 200–400 g/cm² was obtained by stacking successive layers of lead in the paraffin geometry. A transition maximum for neutrons in lead occurs at about 18 g/cm². The relative rates of local production of neutrons give a factor of increase of ~2.8 from carbon to lead. Assuming that nucleons are the incident particles leading to neutron production, the relative multiplicity of neutrons from a nucleus of C, Al, Cu, Sn, or Pb may be determined. The ratio of neutron multiplicity of lead to carbon is ~7.5 which is not in disagreement with the recent measurements of Tongiorgi[2] at lower altitudes.

* Assisted by the Joint Program of the ONR and AEC.
† Deceased.
[1] J. A. Simpson, Jr. and R. B. Uretz, Phys. Rev. **76**, 569 (1949).
[2] V. Tongiorgi, Phys. Rev. **76**, 517 (1949).

M2. Primary Helium Flux in Cosmic Radiation.* L. GOLDFARB, H. L. BRADT, B. PETERS, *University of Rochester.*—Electron sensitive Kodak NTB3 plates were exposed under 16 and 10 g/cm² of air at geomagnetic latitudes of $\lambda = 30°$N and 51°N, respectively. The specific energy loss distribution of particles as measured by their track grain densities is found to show a distinct peak at four times the ionization of a relativistic singly charged particle. This corresponds to the grain density for a relativistic alpha-particle. Many of the particles with this grain density have been uniquely identified as fast He nuclei by the constancy of specific energy loss over long ranges of track (up to 60 g/cm²). Arguments will be presented which show that these He nuclei are not of secondary origin. The following results based on the indicated values for the mean free path for alpha-particles, λ_α, are obtained for the primary flux of He nuclei at the top of the atmosphere:

Flight	Geomagnetic latitude	(Number of alphas/cm² sec. ster.) $\times 10^3$ $\lambda_\alpha = 30$ g/cm²	$\lambda_\alpha = 40$ g/cm²	$\lambda_\alpha = 50$ g/cm²
1	$\lambda = 30°$N	1.1 ± 0.3	0.9 ± 0.3	0.8 ± 0.3
2	$\lambda = 51°$N	4.5 ± 1.5	3.8 ± 1.3	3.4 ± 1.2

According to these values the alpha particles constitute 20–30 percent of the primaries, in agreement with the results of M. A. Pomerantz and F. L. Hereford.[1]

* This work was assisted by the Joint Program of the ONR and the AEC.
[1] Phys. Rev. **76**, 997 (1949).

M3. Magnetic Deflection of Cosmic-Ray Mesons Using Nuclear Plates.* IAN BARBOUR, *University of Chicago.*—A method has been described[1] for investigating the mass and charge sign of mesons by exposing two nuclear plates with an air gap separating their parallel emulsion surfaces in a perpendicular magnetic field. From the orientation of the tracks of a given particle in the two emulsions is computed the radius of magnetic curvature of the trajectory in the intervening air gap, and hence the momentum which, with the range, allows the mass of the particle to be computed. Preliminary results reported[2] have been extended with plates exposed for 6 hours at 90,000 ft. in the 12,800 gauss field of our 65 lb. permanent magnet. Some 150 meson tracks have been analyzed, the signs of the charges determined, and values for the mass computed. In about 30 of these cases the trajectories are long enough to allow good mass determinations with probable errors of the order of 10 to 20 percent. These mass measurements and probable errors will be discussed.

* Assisted by the Joint Program of the ONR and the AEC.
[1] C. F. Powell, Nature **161**, 473 (1948); I. Barbour, Phys. Rev. **74**, 507 (1948).
[2] I. Barbour, Phys. Rev. **76**, 320, (1949).

M4. Concerning the Knock-On Secondaries of Mesons.* FRANK L. HEREFORD,† *Bartol Research Foundation.*—The average number of secondary electrons accompanying a meson traversing and emerging from thin foils of various materials ($t \ll$ radiation length) has been computed using the spin zero collision probability given by Bhabha.[1] The data are of interest in connection with low pressure G-M counter cosmic-ray ex-

periments. The probability, ν, is computed that at least one secondary is produced with sufficient energy to emerge from a foil upon passage of a meson. Families of ν *vs.* t curves for various meson momenta, $P/\mu c$, are thus obtained. For $P/\mu c=10$ the curve for lighter elements ($Z<50$) attains equilibrium for $t\sim1.5$ g/cm² at $\nu=0.075$. This corresponds to $\nu_{Pb}=0.065$ in good agreement with recent experimental results.[2] Computational details and curves will appear elsewhere.[3]

* Assisted by Joint Program of the ONR and the AEC.
† Now at University of Virginia.
[1] H. J. Bhabha, Proc. Roy. Soc. **164**, 257 (1938).
[2] Brown, McKay, and Palmatier, Phys. Rev. **76**, 506 (1949).
[3] J. of Frank. Inst.

M5. East-West Asymmetry of Positive and Negative Mesons.* GERHART GROETZINGER AND GORDON W. MCCLURE, *University of Chicago.*—With a magnetic lens telescope, focusing either positive or negative mesons with an energy of approximately 800 Mev, but excluding protons, the counting rates W_+, W_-, and E_+, E_- of positive and negative mesons coming from the west and east, respectively, were measured for various values of the zenith angle of incidence. The east-west asymmetries $\alpha_\pm=\dfrac{2(W_\pm-E_\pm)}{W_\pm+E_\pm}$ and the positive excess $\beta=\dfrac{2(W_++E_+-W_--E_-)}{W_++E_++W_-+E_-}$ were found to be:

Zenith angle	Mt. Evans (Altitude 14,000 feet) 24°	58°	Chicago 17°
	$\alpha_+=+\ 7.1\pm2.1\%$	$\alpha_+=+61.3\pm6.1\%$	$\alpha_+-\alpha_-=12.7\pm3.2\%$
	$\alpha_-=-\ 5.6\pm2.1\%$	$\alpha_-=-37.4\pm6.0\%$	
	$\beta=\ 17.6\pm1.2\%$	$\beta=\ 7.4\pm2.8\%$	$\beta=12.0\pm1.4\%$

Our data thus indicate: (a) The east-west asymmetry is greater for positive than for negative mesons. A possible explanation may be that positive mesons are on the average produced at a higher altitude. (b) The positive excess increases with decreasing zenith angle and altitude, which is in agreement with results previously obtained by others.

* Assisted by the Joint Program of the ONR and the AEC.

M6. Multiple Production of Mesons. E. P. NEY AND PHYLLIS FREIER, *University of Minnesota.*—Definite examples of multiple production of mesons have been observed in cloud chambers and supporting evidence obtained in photographic emulsions. The multiplicity and angular distribution in carbon and lead will be discussed.

M7. Properties of the Heavy Primaries. PHYLLIS FREIER, E. P. NEY, F. OPPENHEIMER, *University of Minnesota.*—Recent results concerning the energy distribution and the mean free path of the heavy primaries will be discussed.

M8. Electrical Detection of Artificially Produced Mesons. L. W. ALVAREZ, A. LONGACRE, V. G. OGREN, AND R. E. THOMAS, *University of California, Berkeley.*—Scintillation counters have been used to detect the electrons from the decay of μ-mesons. The decay of the μ-meson has been followed over an intensity range of almost 10^4, and the measured mean life is 2.09 ± 0.03 μ-sec. The fact that this may be less than the free space lifetime may be explained by the presence of a small component of negative μ's. Almost all of the μ's are positive, as they come from the decay of π's. Although the latter have both signs, negative π's produce stars in matter and so do not give negative μ's unless the process occurs "in flight." Now that the technique has been shown to be reliable, it becomes possible to determine the energy spectrum, the angular distribution, and the total cross sections for the production of positive π-mesons as functions of Z and the proton-bombarding energy. For such determinations, the μ-decay is used as a "tracer," to tell where a π-meson has ended its range. Since the combined ranges of the μ and electron are small compared to the π-range, no appreciable errors are introduced by the tracer technique.

11:45 o'clock

Invited Paper on Microwave Spectroscopy

M9. Recent Work on Microwave Spectroscopy at the State University of Iowa. ARTHUR ROBERTS, *State University of Iowa.* (30 min.)

SATURDAY MORNING AT 9:45

Eckhart 133

(N. HILBERRY presiding)

Reactions of Transmutation

N1. *P-N* Thresholds for Calibration Points on the Nuclear High Voltage Scale.* H. T. RICHARDS AND R. V. SMITH, *University of Wisconsin.*—The nuclear absolute voltage scale established by Herb, Snowdon, and Sala[1] has been extended to higher energies by accurate determinations of the $p-n$ thresholds of Be^9, B^{11}, C^{13}, and O^{18}. The same electrostatic proton analyzer with slits adjusted for 0.1 percent resolution was used for bombarding heated thin targets of Li, Be, B, TaO_2, and a thick carbon target. The proton energies in Mev at the observed neutron thresholds are as follows:

Li^7	Be^9	B^{11}	C^{13}	O^{18}
1.882 (Standard)	2.059	3.015	3.236	2.592

The largest uncertainty in these values is believed to be the 0.1 percent uncertainty in the Li standard.

* This work was supported in part by the AEC and in part by the Wisconsin Alumni Research Foundation.
[1] Herb, Snowdon, and Sala, Phys. Rev. **75**, 246 (1949).

N2. A Comparison of Several Nuclear Absolute Voltage Determinations. WILLIAM J. STURM AND VIRGIL JOHNSON, *University of Wisconsin.*—An experiment has been performed which was designed to evaluate the consistency between the absolute voltage determination of the threshold energy of the $Li^7(p, n)Be^7$ reaction as measured by Herb, Snowdon, and Sala[1] and earlier independent absolute voltage measurements.

The comparison was effected by employing the natural alpha-particles from polonium and radium C′, the energy of which has been measured absolutely by several authors using magnetic deflection methods.[2] In this comparison the alpha-particles from these substances have been deflected electrostatically in the 90° cylindrical electrostatic analyzer at the University of Wisconsin. Alpha-particle line measurements were analyzed by numerical integration of resolution and source functions and in themselves contributed negligibly to the uncertainties of the comparison. The resulting alpha-particle energies, evaluated by comparison with the energy of the $Li^7(p, n)Be^7$ threshold, agree with the earlier measurements, and indicate that within the limits of accuracy of Herb's determination, all determinations give identical results.

[1] Herb, Snowdon, and Sala, Phys. Rev. **75**, 246 (1949); cf. also Schoupp, Jennings, and Jones, Phys. Rev. **76**, 502 (1949).
[2] S. Rosenblum and G. Dupouy, J. Phys. Rad. **4**, 262 (1933); W. W. Lewis and B. V. Bowden, Proc. Roy. Soc. **145**, 235 (1934); G. H. Briggs, Proc. Roy. Soc. **157**, 183 (1936).

N3. Fast Neutron Yield From the Cyclotron.* A. J. ALLEN AND J. F. NECHAJ, *University of Pittsburgh*, AND K. H. SUN AND B. JENNINGS, *Westinghouse Research Laboratories*.—Previous measurements of the fast neutron yield from various thick targets bombarded with 15-Mev deuterons and 30-Mev alphas have been extended.[1] The reaction, $S^{32}(n, p)P^{32}$, was used for neutron detection and defines the term "fast" neutron. The total neutron yield, N, obtained from angular distribution data, was found to be (410, 320, 290, 280, 168, 150, 137, 33, and 21)$\times 10^7$/sec./μa deuterons for Ti, Cr, Co, Cu, Cb, Mo, Ag, Ta, and Pb targets respectively, and (650, 189, 106, 105, 42, 6.5, and 4.6)$\times 10^7$/sec./μa alphas for Be, Al, Co, Cu, Ag, Au, and Bi targets respectively. For data obtained thus far, N may be calculated from the nuclear charge, Z, of the target by the empirical relationships: $\log N = 10.18 - 0.024Z$ (for deuterons) and $\log N = 9.72 - 0.024Z$ (for alphas). There is evidence that the strong forward neutron peak reported previously may be resolved into double or triple peaks.

* Assisted by the Joint Program of the AEC and the ONR.
[1] Allen, Nechaj, Sun, and Jennings, Phys. Rev. **76**, 188, 463 (1949).

N4. Deuterium (p, n) Threshold and the Deuteron Binding Energy.* R. V. SMITH AND D. H. MARTIN, *University of Wisconsin*.—The threshold has been carefully investigated for the previously reported $D(p, n)2H$ reaction.[1] Protons from the Wisconsin electrostatic generator, limited to 0.1 percent energy spread by the cylindrical electrostatic analyzer and calibrated in energy against the $Li(p, n)Be$ threshold, were used to bombard a target of frozen ND_3. The reaction neutrons, which at threshold are collimated forward and monoenergetic at 370 kv, were detected with a small hydrogen recoil counter biased to count only neutrons above 100-kv energy.

A preliminary evaluation of the data has been made, using for extrapolation near threshold a theoretical cross section curve which is based upon a $1/v$ law for the outgoing neutrons and coulomb barrier penetration for the outgoing protons. This extrapolation gives 3.346 ± 0.015 Mev for the threshold proton energy, and -2.231 ± 0.010 Mev for the reaction Q. This Q-value is then directly the deuteron binding energy.

* This work was supported in part by the AEC and in part by the Wisconsin Alumni Research Foundation.
[1] R. V. Smith and H. T. Richards, Phys. Rev. **74**, 1871 (1948).

N5. Photo-disintegration of Deuterium by 4.5 to 20.3-Mev X-Rays.* EVERETT G. FULLER, *University of Illinois*.—Nuclear emulsions have been used to detect the photo-protons produced by the passage of the collimated x-rays from a thin target (0.005-in. Pt.) betatron doughnut through a deuterium gas filled scattering chamber. The preliminary analysis of these plates has been reported.[1] Using the quanta distribution with energy for a thin target betatron determined by Koch and Carter,[2] the observed distribution of the photo-protons, after correction for the neutron background, was used to obtain a curve for the relative cross section of the photo-disintegration process as a function of photon energy. This curve falls off slower than the Bethe-Peierls expression. At high energies it goes as $1/(h\nu)^4$. Angular distributions indicate a differential cross section in the center of mass system, obeying a $\sin^2\theta$ law at low energies. For energies above 10 Mev the data are fitted by a $\sin^2\theta(1+\alpha\cos\theta)$ law. There is no evidence for an isotropic component except in the high energy group (mean photon energy of 17 Mev), where the data are fitted by the expression: $\sin^2\theta(1+0.4\cos\theta)+0.15$.

* This work was assisted by the Joint Program of the ONR and AEC.
[1] E. G. Fuller, Phys. Rev. **76**, 576 (1949).
[2] H. W. Koch and R. E. Carter, Phys. Rev. **75**, 1950 (1949).

N6. Angular Distribution of Photo-Protons from Deuterium.* GERSON GOLDHABER, *University of Wisconsin*.—The angular distribution of photo-protons from the $D^2(\gamma, n)H^1$ reaction was measured in photographic emulsions loaded with deuterium and exposed to $F^{19}+H^1$ gamma-rays. The emulsions (Eastman, NTA, 100μ) were loaded by soaking in D_2O and were exposed while wet together with control emulsions loaded with H_2O (D_2O content 50 percent of emulsion weight). The gamma-rays were obtained by bombarding a thick CaF_2 target with 2.6-Mev protons from the Wisconsin electrostatic generator. A 35 μamp. hr. exposure was used. The emulsions were exposed at an average distance of 12.5 cm from the target, with the plane of the emulsion containing the proton beam direction. All the information is thus obtained on a single emulsion. The scanning of the emulsions is still in progress. To date ~600 acceptable tracks were found on an area of 40 mm^2 of the D_2O emulsion. The number of tracks on the H_2O emulsion of the same range is negligible. The two gamma-ray lines from $F^{19}+H^1$ at 6.13 and 7.00 Mev are clearly resolved, when the angular dependence of photo-proton energy is taken into consideration. The present preliminary value of a/b for the two gamma-rays combined is ~0.1 (where the angular distribution is of the form $a+b\sin^2\theta$).

* This work was supported in part by the AEC and in part by the Wisconsin Alumni Research Foundation.

N7. Differential Cross Section of the Reaction $He^3(d, p)He^4$ at 10.2-Mev Bombarding Energy and Search for Excited State in He^4. J. C. ALLRED, *Los Alamos Scientific Laboratory and University of Texas*.—Measurements of the differential cross section of the reaction $He^3(d, p)He^4$ at 10.2-Mev bombarding energy have been made using the focused cyclotron beam by means of a nuclear multiple photographic plate camera recently constructed at the Los Alamos Laboratory. The camera-target arrangement used permitted simultaneous observation of the reaction protons at laboratory angles from 20° to 155°. In the center of mass system the differential cross section shows two minima at 44° and 112°, the peak between them occurring at 65°. For the angular region investigated the cross section varied between two and five millibarns/unit solid angle. A comparison was made of the low energy particle spectrum from He^3 with that of H^3 and He^4 bombarded under similar conditions. The results indicate that, at a proton angle of 90° lab, residual excited He^4 nuclei are not produced with a cross section as great as 0.2 millibarn/unit solid angle for an excited level as high as 20.9 ± 0.4 Mev. Values of the differential cross section at 5° intervals will be given and limits of the excited level energy as determined at 45° lab will be discussed.

N8. The Energies of Neutrons from the $Be^9(\alpha, n)$ Reaction. C. E. BRADFORD AND W. E. BENNETT, *Illinois Institute of Technology*.—A thick beryllium target was bombarded with 1.4 Mev α-particles produced in a Van de Graaff machine.

The neutron spectrum was inferred by measuring the tracks of recoil protons in an Ilford C2 plate placed at 90° to the target. Two groups of neutrons were found. The group of higher energy corresponded to the formation of C^{12} in the ground state, and the Q-value derived from the masses (5.72 Mev) was used to find the stopping power of the plates. The second group of neutrons was found to have a Q-value of 1.27 Mev, yielding 4.45 Mev as the energy of the excited state of C^{12}. Lower excited states were definitely missing. Any excited state higher than 6 Mev would not have been observed at this low bombarding energy. The yield of neutrons in the low energy group was 1.30 times the yield of high energy neutrons. A plate exposed in the forward direction gave 0.40 for this ratio, as indication that the angular distribution of the two groups is different.

N9. Interpretation of the Angular Distribution of Long and Short Range Protons from the $O^{16}(d, p)O^{17}$ Reaction. LEO DIESENDRUCK, *Rhode Island State College.*—The theoretical expansion of the resonance formula for nuclear reactions for the differential cross section of an unpolarized reaction leads to a power series in the cosine, the coefficients of which are the sums of many terms each of which contains three types of factors: energy dependent (functions of the resonance denominators and "penetration" factors), "kinematic" (depending only on the quantum numbers), and unknown complex (arising from the matrix elements). The experimental results[1] show a fourth power of the cosine and odd powers necessary for both groups and for the long-range case (spin of $\frac{1}{2}\,h$ and even parity for the ground state of O^{17}) are consistent with resonant levels located at 1.4 Mev, 2.00 Mev, and 2.60 Mev and widths 0.5 Mev. The complexity of the distribution sets a lower value and estimates of the penetrability set an upper value to the permitted angular momentum quantum numbers. Evaluation of the "kinematic" factors permits further limitations and the best choice of states for the three levels giving the long-range protons is $J=2^+$, 1^-, and 3^+. The complete theoretical expansion for these assumptions can be checked by attempting a fit of the experimental results, evaluating the unknown complex factors under the assumption that their magnitudes are not too different.

[1] N. P. Heydenburg and D. R. Inglis, Phys. Rev. **73**, 230 (1948).

N10. Angular Distribution of Photo-Protons from Magnesium.* M. E. TOMS, J. HALPERN, AND W. E. STEPHENS, *University of Pennsylvania.*—The protons ejected from a four-mil magnesium foil by the bremsstrahlung from 22.5-Mev electrons were observed in Ilford C-2 emulsions. The magnesium foil was irradiated by 13,500 roentgen units in the $\frac{1}{4}$-in. diameter beam defined by a collimator in front of a betatron. Several Ilford plates (1 in.$\times\frac{1}{4}$ in., 100 microns thick) were placed at various angles and one inch from the target so as to intercept the protons with glancing incidence. Equal areas (24 mm²) of five plates were scanned and 423 protons found which entered the top surface of the emulsion and pointed from the target. The background of recoil protons was small enough to require no correction to the photo-protons. The angular distribution of photo-protons was observed to be: 30°, 79; 60°, 80; 90°, 93; 120°, 65; 150°, 106. The energy distribution of the protons as inferred from the measured range corrected for the target thickness is: 2–3 Mev, 34; 3–4 Mev, 83; 4–5 Mev, 82; 5–6 Mev, 68; 6–7 Mev, 86; 7–8 Mev, 58; 8–9 Mev, 18; 9–10 Mev, 3. From induced radioactivities, it was estimated that less than 5 percent of the protons were produced by the $Mg^{24}(n, p)$ reaction, that $\frac{3}{4}$ of the protons were probably from $Mg^{25}(\gamma, p)$ and $\frac{1}{4}$ from $Mg^{26}(\gamma, p)$.

* Supported by the Joint Program of the ONR and the AEC.

N11. $P-N$ Reactions in Light Elements.* C. P. BROWNE, R. V. SMITH, AND H. T. RICHARDS, *University of Wisconsin.*—The yield of neutrons from $Be^9(p, n)B^9$, $O^{18}(p, n)F^{18}$, and $K^{41}(p, n)Ca^{41}$ has been investigated from threshold to about 3.5-Mev proton energy. For the Be reaction a thin evaporated target was used. No resonance structure was observed except that at 2.56 Mev previously reported by Hushley.[1] For the O^{18} reaction, thin TaO_2 and Al_2O_3 targets were prepared by electrolyzing water enriched to 1.5 percent O^{18}. Resonances in the forward direction neutron yield were observed at the following proton energies: 2.78, 3.05, 3.29, 3.40, and 3.50 Mev. For the potassium reaction, thin K_2O targets were used. Resonances in neutron yield were observed at the following proton energies: 1.60, 1.90, 2.24, 2.46, 2.60, 2.80, 2.96, and 3.12 Mev. The K^{41} threshold was observed at 1.258 ± 0.01 Mev in agreement with the previous value 1.25 ± 0.05 Mev.[2] Work is in progress on $p-n$ reactions in chlorine and iron.

* This work was supported in part by the AEC and in part by the Wisconsin Alumni Research Foundation.

[1] W. J. Hushley, Phys. Rev. **67**, 34 (1945).
[2] H. T. Richards and R. V. Smith, Phys. Rev. **74**, 1257 (1948).

N12. The $(n-2n)$ and $(n-p)$ Cross Sections. BERNARD L. COHEN, *Carnegie Institute of Technology.*—The cross sections of about $15(n-2n)$ and $30(n-p)$ reactions produced by neutrons from the University of Pittsburgh 47-inch cyclotron were measured by counting the induced activity of the product isotopes. Corrections were made for the self-absorption of the beta-rays and for all other recognizable factors. Due to the slow variation of these cross sections with energy, the results could be readily integrated over the energy spestrum of the neutrons and compared with the predictions of Weisskopf's Nuclear Statistics.* The neutron energy spectrum was determined by proton recoils in a photographic plate, and in a triple coincidence—anticoincidence counter telescope with aluminum absorbers. Although fair agreement was found in several cases, there were deviations that are not consistent with any reasonable choice of nuclear temperatures. The results will be discussed in connection with the degree of validity of statistical theories of nuclei, and applications will be suggested to the identification of doubtful isotopes and the use of threshold detectors for determining neutron energies. This work was done with the assistance of the ONR.

* See, for example, "Lecture series in nuclear physics" MDDC 1175.

N13. The Values of Certain (p, γ) Resonances Below 400 Kv. S. K. ALLISON, J. H. MONTAGUE, AND A. H. MORRISH. *University of Chicago.*—A cylindrical electrostatic deflector has been constructed with average radius 15 cm, spacing 0.5 cm, and 90° deflection, in which the deflecting potential can be in the neighborhood of 50 kv, focusing protons up to 750 kv. Movable slits have been incorporated in the design and the geometry of the entrance and exit apertures of the deflecting channel is such that the stray field may be calculated analytically. The predictions have been compared with experiments on the focusing of electron beams by the instrument under controlled conditions and agreement to within 0.3 percent has been demonstrated. The instrument has been used to measure the lower voltage thresholds of the $F^{19}(p, \alpha, \gamma)$ and the $B^{11}(p, \alpha)$ and $B^{11}(p, \gamma)$ resonances, obtaining 0.3404 ± 0.0004 Mev for fluorine and 0.1628 ± 0.0002 for boron respectively. The agreement is good with recent measurements of Tangen[1] and Heydenburg.[2]

[1] R. Tangen, Kgl. Norske. Vid. Sels. Skrifter (1946) NRI.
[2] N. P. Heydenburg (private communication).

N14. The Low Energy Cross Section and Angular Distribution of the $D(d, p)$ Reaction. J. H. SANDERS,* J. MOFFATT, AND D. ROAF, *Oxford University.*—A thin deuterium target has been used to study the $D(d, p)$ reaction at low energies.[1,2] Using beams of from 35 μA to 250 μA of analyzed deuterons and a nuclear emulsion camera which favored the detection

of low yields, sufficient proton tracks could be counted to measure the cross section and the angular distribution down to 15-kev bombarding energy. The deuteron beam was admitted to the camera through two successive canals, with differential pumping between them to reduce the gas flow into the accelerator. A velocity-selector type analyzer was used, and the beam intensity was measured calorimetrically owing to the large amount of ionization and charge-exchange in the target gas. The distribution can be represented as $Y_\theta = Y_{90°}(1+A\cos^2\theta)$. Values of A and the integrated cross-section σ are tabulated below:

Ekv	14.53	19.45	24.33	29.13	33.88	38.82	50.00
A	0.207	0.223	—	0.274	—	0.308	0.374
$\sigma\times10^{29}$	7.06	24.8	59.6	112.0	176.0	255.0	—

* Now at National Research Council of Canada, Chalk River, Ontario.

[1] A. P. French, Phys. Rev. **73**, 1474 (1948).
[2] Bretscher, French, and Seidl, Phys. Rev. **73**, 815 (1948).

SATURDAY MORNING AT 10

Rosenwald Hall

(I. I. RABI presiding)

Miscellany of Nuclear Experiments; Theoretical Nuclear Physics

P1. Resonance Scattering of X-Rays by Atomic Nuclei.* RALPH DRESSEL, M. GOLDHABER, AND A. O. HANSON, *University of Illinois.*—An attempt has been made to detect possible resonance radiation expected on the basis of the nuclear model suggested by Goldhaber and Teller.[1] Using x-rays from the 22-Mev betatron the radiation scattered from lead at 90° and 145° was measured by the 3.3-minute activity from the $Pr^{141}(\gamma, n)Pr^{140}$ reaction. Absorption measurements indicated that about half the activity could be attributed to fast neutrons from the scatterer. Comparison of the angular distribution of the remaining activity with that from 17-Mev electrons on thick lead indicated that about 50 percent of this activity at 90° and 5 percent of that at 145° might be associated with bremsstrahlung generated in the scatterer by multiple processes. The residual activities indicate differential cross sections for nuclear scattering in lead of (1.1 ± 0.6) and $(2.0\pm1.0)\times10^{-27}$ cm² per steradian, at 90° and 145° respectively. These values are approximately those expected from the above model using a resonance width of 4 Mev. Scattering from lighter elements was considerably less in agreement with the observations of Gaerttner and Yeater.[2]

* This work was supported by the Joint Program of the ONR and AEC
[1] M. Goldhaber and E. Teller, Phys. Rev. **74**, 1046 (1948).
[2] E. R. Gaerttner and M. L. Yeator, Phys. Rev. **76**, 363 (1949).

P2. The Penetration of Protons in Several Metals. T. A. HALL AND S. D. WARSHAW,* *University of Chicago.*—The energy loss and average charge of fairly low energy protons (from 50 to 400 kev) passing through thin metallic foils have been studied for five elements: Be, Al, Cu, Ag, and Au. The data should be more accurate than previous results[1] because of improvements in the preparation and measurement of the thin foils[2] and the greater precautions taken against oil vapor effects in the vacuum system. At the energy extremes, the stopping data are consistent with the low energy theory of Fermi and Teller[3] and the high energy theory of Bethe,[4] but neither theory applies well in the energy range studied.[5] The data on average ionic charge will be compared with Bohr's estimates.[6]

* This work was in part supported by the Joint Program of the ONR and the AEC.
[1] H. Wilcox, Phys. Rev. **74**, 1747 (1948); Hall and Warshaw, Phys. Rev. **75**, 891 (1949).
[2] S. D. Warshaw, Rev. Sci. Inst. **20**, 623 (1949).
[3] E. Fermi and E. Teller, Phys. Rev. **72**, 399 (1947).
[4] M. S. Livingston and H. A. Bethe, Rev. Mod. Phys. **9**, 264 (1937).
[5] S. D. Warshaw, Phys. Rev. (to be published).
[6] N. Bohr, *The Penetration of Atomic Particles through Matter* (Copenhagen, 1948).

P3. Fission Yields of 65*d* Zr^{95} and 17*h* Zr^{97}; Search for Other Zr and Nb Fission Chains.* C. D. CORYELL, A. Y. SAKAKURA, AND A. M. ROSS, *Massachusetts Institute of Technology.*—No precise values have been reported[1] for fission yields of chain 95 (65*d* Zr−35*d* Nb) and chain 97 (17*h* Zr −75*m* Nb) in U^{235} fission. Values of 6.0 ± 0.3 percent and 6.2 ± 0.3 percent respectively are found by chemical separation of zirconium. Search for other zirconium fission activities (of mass numbers 93, 98, 99, 100) of half-life between 2*m* and 65*d* gave negative results; other work[1-3] also eliminates activities in appreciable yield of periods between 2*m* and 100*y*. Calculations indicate minimum half-lives for Zr^{93} and Zr^{98} of 1.7*d* and 1.5*m* respectively. It is thus shown that Zr^{93} is very long-lived; Zr^{98} might have been missed. Samples of niobium (columbium) separated rapidly after fission fail to show any short-lived constituent of half-life between 10*m* and 10*h* except 75*m* Nb^{97}, although 30*m* Nb^{98} has been reported to exist.[4] If Zr^{98} has a short life, Nb^{98} should have been found here unless its half-life is less than 10*m*.

* Assisted by the Joint Program of the ONR and the AEC.
[1] The Plutonium Project, J. Am. Chem. Soc. **68**, 2411 (1946); Rev. Mod. Phys. **18**, 513 (1946).
[2] S. Katcoff and L. J. Brown, J. Chem. Phys. **17**, 505 (1949).
[3] L. Jacobson and R. Overstreet, paper 91, Vol. 9, Div. IV, Nat. Nucl. En. Series (in press).
[4] G. E. Boyd, private communication to G. T. Seaborg and I. Perlman, Rev. Mod. Phys. **20**, 607 (1948).

P4. Further Interpretations of Closed-Shell Perturbations in Fission Yields.* L. E. GLENDENIN** AND C. D. CORYELL, *Massachusetts Institute of Technology.*—In previous papers[1,2] the authors have treated the distribution of nuclear charge in fission and showed that there is a pronounced perturbation in fission yields caused by enhanced stability of fission fragments with 50 or 82 neutrons. At present two competitive hypotheses exist which are in fair agreement with the mass spectrometric observations of Thode on xenon fission yields and of Nagle on the ratio of the yields of Cs^{135} to Cs^{137} (1.1 ± 0.1). The first hypothesis is that primary fission fragments with 83 neutrons eject promptly an extra neutron, and the yield of primary fission fragments is that set by the postulate[1] of equal charge displacement of light and heavy fragments; the second is an elaboration[1] of the theory of the division of charge in fission of Present. For some interesting chains, the ratio of observed fission yields to smooth-curve[3] yields are: *132* 1.00; *133* 1.26; *134* 1.35; *135* 1.0_2; *136* 1.0_2; *137* 0.8_8. It is seen that the effects are large; it will be shown that they are understood semi-quantitatively.

* Assisted by the Joint Program of the ONR and the AEC.
** Presently at the Argonne National Laboratory, Chicago, Illinois.
[1] Glendenin, Coryell, and Edwards, paper 52, Vol. 9, Div. IV, Nat. Nucl. En. Series (in press); Phys. Rev. **75**, 337 (1949).
[2] L. E. Glendenin, Ph.D. thesis in Chem. M.I.T. (August, 1949); Phys. Rev. **75**, 337 (1949).
[3] The Plutonium Project, J. Am. Chem. Soc. **68**, 2411 (1946); and also Rev. Mod. Phys. **18**, 513 (1946).

P5. Properties of Deuteron and Triton from h.f.s. Measurements. EDWARD N. ADAMS II,* *University of Wisconsin.*—Using Aage Bohr's model[1] of deuterium it is found that there is a contribution to the anomaly in the deuterium h.f.s. due to the small orbital moment of the deuteron. This contribution is of the order $2D/a$ relative to the total h.f.s. contribution of the orbital moment, in which D denotes the radius of the adiabatic region[1] and a the Bohr radius. Estimates of D indicate that this effect may be large enough to provide a new relation between the ^3D probability in the deuteron and the range of the neutron-proton interaction if experimental uncertainties can be reduced somewhat.[2] The adiabatic approximation should be equally valid in the case of tritium, which has no h.f.s. anomaly. For reasonable estimates of D conclusions can be drawn about several possible explanations of the anomaly in the triton magnetic moment.

* AEC predoctoral fellow.
[1] Aage Bohr, Phys. Rev. **73**, 1109 (1948).
[2] However, calculations of this effect by Francis Low (private communication) indicate that the adiabatic model may be too crude for accurate calculations.

P6. Relativistic Meson Theory of the Deuteron. S. M. DANCOFF, *University of Illinois.*—The properties of the deuteron have been studied on the basis of scalar and pseudoscalar meson theories in a treatment which considers the nucleons to obey the Dirac equation. Weak coupling was assumed. For separations larger than the nucleon Compton wave-length, the conventional potential expressions are derived in the low velocity limit. Relativistic corrections introduce (1) the "Thomas precession" spin-orbit coupling, first postulated for nuclei by Inglis; and (2) higher order spin-orbit couplings. Spin-orbit coupling energies are invariably characterized by very singular dependences on separation. However, for separations less than the nucleon Compton wave-length, the notion of a point potential energy does not apply; the singular potentials have no significance for this region. Instead one can solve directly for the binding energy of the lowest state; this binding energy is always finite. It remains to be determined to what extent one can account quantitatively for the phenomenological properties of the deuteron with the introduction of a single (coupling) constant. It is interesting that with the relativistic treatment, even the scalar theory permits a qualitative account of all the deuteron properties and is to be discarded, if at all, only on the basis of numerical disagreement.

P7. On Generalized Meson Theories.* ALEX E. S. GREEN, *University of Cincinnati.*—Choosing an approximate deuteron wave function we calculate energy expectation values to show that a generalized, multiple meson, weak coupling theory predicated only upon relativistic pole interactions or non-relativistic dipole interactions is numerically feasible. The closely related fact that our potential function corresponds to a deep spherical well at nuclear ranges suggests the interpretation that the interaction of nucleons is due to the virtual emission and absorption of connected meson complexes (super-particles) or interfering meson waves (a super-superposition). We call attention to a marked confluence of some consequences of recent work by Born and Green,[1] Pauli and Villars,[2] DeBroglie[3] and others with those of our own work despite divergent premises and interpretations.

* A. Green, Phys. Rev. **73**, 26, 519 (1948); **75** (1926); **76**, 460, 871 (1949).
[1] M. Born and H. S. Green, Nature **163**, 207, 208 (1949).
[2] W. Pauli and F. Villars, Rev. Mod. Phys. **21**, 434 (1949).
[3] L. DeBroglie, Phys. Rev. **76**, 862 (1949).

P8. Theory of the D+D Reactions: Analysis of the Energy Dependence.* F. M. BEIDUK,** J. R. PRUETT, AND E. J. KONOPINSKI, *Indiana University.*—The variations with energy of the newly extended observations on the D+D reaction products are analyzed. It is found adequate to assume that all these variations, including details of the angular distributions, are due to differences in centrifugal barriers met by different components of the incident deuteron waves. This is found possible only if considerable spin-orbit interaction is allowed for. The possibility is investigated that numerical measures of the interactions can be obtained from the experimental data. Such conclusions as are permitted by the nature of the data are presented.

* Supported in part by Joint Program of the AEC and the ONR.
** AEC Fellow.

P9. Theory of the D+D Reactions: Relation to the Internucleonic Forces.* J. R. PRUETT, F. M. BEIDUK,** AND E. J. KONOPINSKI, *Indiana University.*—The adequacy of current ideas about the internucleonic forces in accounting for the observations as analyzed in the foregoing abstract is investigated. In particular, the adequacy of the spin-orbit coupling provided by the tensor forces is examined. To this end, a "minimal" formulation of the four-body problem is attempted. The interaction responsible for the reaction is derived. Some order-of-magnitude comparisons with the experimental data are presented.

* Supported in part by Joint Program of the AEC and the ONR.
** AEC Fellow.

P10. Dipole Transitions in the Nuclear Photo-Effect. J. S. LEVINGER AND H. A. BETHE, *Cornell University.*—The G. E. experiments[1] on the cross section and energy dependence of the nuclear photo-effect indicate strong dipole transitions. Using sum rules for dipole transitions, we find agreement with the general features of their experiments. We do not need to assume dipole vibration of the entire nucleus.[2] Exchange forces modify the sum rules.[3] The summed oscillator strength for dipole transitions for heavy nuclei becomes $\Sigma f_{on}=(NZ/A)\times(1+0.8x)$. (Here N is the number of neutrons; and x is the fraction of attractive exchange force.) For $N=Z$ $\int\sigma dW=0.015A\ (1+0.8x)$ Mev-barns. The mean energy for photon absorption is about 20 Mev for pure ordinary forces, and is greatly increased by attractive exchange forces. From another sum rule we show that quadrupole transitions can account for only about 6 percent of the experimentally determined integrated cross section.

[1] Lawson and Perlman, Phys. Rev. **74**, 1190 (1948); Baldwin and Klaiber. Phys. Rev. **73**, 1156 (1948).
[2] M. Goldhaber and E. Teller, Phys. Rev. **74**, 1046 (1948).
[3] Siegert, Phys. Rev. **52**, 787 (1937).

SATURDAY AFTERNOON AT 2:15

Rosenwald Hall

(S. M. DANCOFF presiding)

Nuclear and General Theory

S1. Magic Numbers and the Principle of Continuity and Regularity of Nuclear Series. WILLIAM D. HARKINS AND M. POPELKA, *University of Chicago.*—In a series of 24 papers (1915 to 1923) Harkins showed that *the most important of all "magic" nuclear numbers is two for protons and two for neutrons, giving four for nucleons.* This is illustrated by the latest data

(Greenstein) which show that *the cosmic abundance of helium is 70 times that of all other elements* (hydrogen excluded). In the building of nuclei from neutrons (protons also for light atoms) the same general stability relations rule as for the naturally radioactive series (except a *general* decrease in stability with increase in mass). If the uranium 238 disintegration series is continued to heavy hydrogen, there are 83 species: only one of these, $_{38}Sr^{90}$, is unstable. In the Helium-Thorium series 85 species are stable: five unstable. No even-even nucleus is stable which does not belong to the He−Th or the H^2−U^{238} series. Of the 173 species in both series each of the unstable six is adjacent to but not at the end of a nuclear shell. The seemingly abnormal existence of $_{20}Ca^{48}$ is due to the magic 20.

S2. The Principle of Continuity as Related to the Existence of Stable Even *N*-Odd *P* and Odd *N*-Even *P* Nuclei. MARTIN POPELKA AND WILLIAM D. HARKINS.—The continuity principle indicates two isotopes each for elements 43 and 61. However, these should not exist in nature, since they are adjacent isobars to stable species: thus elements 43 and 61 do not exist in nature. If all stable nuclear species of odd mass (nucleons) are considered as a single series, an extremely interesting pattern, *very unlike* that for the even-even series, is revealed. When plotted as number of extra neutrons (I) against the number of protons (P) all species arrange themselves in 23 single horizontal steps, which are neither below nor above other steps, except at the end. *Thus there is only one isotope per element except at the end of a step* where the pattern exhibits an increase of I to the next higher odd value, except between $P=44$ Ru and $P=56$ Ba. In the region $P=56$ to 62 the pattern is greatly disturbed by the end of the 82 neutron shell. Here four species adjacent to the 82 neutron shell are missing: 80NLa, 81NCe, 83NCe, 84NPr (N=neutrons).

S3. The Low States of Li^7.* C. H. BLANCHARD AND R. AVERY, *University of Wisconsin.*—Recent measurement[1] shows that the Li^7 quadrupole moment is positive. This result was unexpected since previous theory[2] predicted a negative value. Assuming an s^4p^3 configuration, we find that only one spin and angular dependence for the wave function is consistent with the positive quadrupole moment as well as other known data (spin; magnetic moment; $Be^7 \xrightarrow{K} Li^{7*}$, Li^7 lifetime and branching ratio). This wave function, 80 percent D and 20 percent P state, is necessarily very different from the wave function predicted by the previous theory. The validity of the analysis depends on the accuracy of the assumption that the quadrupole moment is due only to the charge distribution of the nucleons, with no contribution arising from their interaction. Similar analysis shows that assigning the s^4p^3 configuration and a spin 5/2 to the 480 Kev excited state is consistent with experimental data ($Li^{7*} \rightarrow Li^7 + \gamma$ lifetime; Be^7 K-capture data). The inability of any s^4p^3, spin $\frac{1}{2}$ function to agree with these data is considered further evidence favoring the higher value of the excited state spin.

* Work supported by the AEC.
[1] Kusch, Phys. Rev. **76**, 138 (1949).
[2] Feenberg and Wigner, Phys. Rev. **51**, 95 (1937).

S4. Evaluation of $f_{\pm}(Z, W_0)$ in the Fermi Theory of Beta-Decay.* GEORGE L. TRIGG, *Washington University.*—The values of $f_{\pm}(Z, W_0)$,[1] the integral of the allowed distribution function in Fermi theory of beta-decay, are necessary for the evaluation of the ft product. Since the charts given by Konopinski are inconvenient in form for the interpretation of a large quantity of data, and since their accuracy is not uniform over the entire range of the variables, it was found desirable to calculate the values of f_- itself and plot them as a function of W_0 for values of Z in steps of 10 from 0 to 100 for negatron emitters. For positron emitters the function f_k which plays the analogous part in K- capture theory was also evaluated; the sum and the ratio of f_+ and f_k are plotted as functions of W_0 for Z in steps of 10, from 0 to 80. The mathematical methods used in arriving at the values are discussed, including the Nordheim and Yost[2] approximation and its limitations.

* Assisted by the Joint Program of the ONR and the AEC.
[1] E. J. Konopinski, Rev. Mod. Phys. **15**, 209 (1943).
[2] L. W. Nordheim and F. L. Yost, Phys. Rev. **51**, 942 (1937).

S5. The Interpretation of ft Values in the Fermi Theory of Beta-Decay.* EUGENE FEENBERG, *Washington University.*—The ft product in the Fermi theory of beta-decay provides a useful criterion for the classification of radioactive transitions as allowed or forbidden to various degrees.[1] Using f values computed by G. L. Trigg (see preceding abstract) tables have been prepared including all transitions for which the determination of energy, half life and branching ratios is sufficiently complete to permit the calculation of the ft product. Separate histograms have been prepared, for odd and even mass numbers, showing the distribution of $lgft$ values for transitions between ground states. These histograms provide useful information for the study of: (a) the correct covariant formulation of the beta-decay theory and (b), the type of coupling between orbital and spin angular momenta in nuclei.

* Assisted by the Joint Program of the ONR and the AEC.
[1] E. J. Konopinski, Rev. Mod. Phys. **15**, 209 (1943).

S6. Multiple Scattering. MELVIN LAX, *Syracuse University.*—Foldy's[1] treatment of the multiple scattering of waves by isotropic scatterers has been generalized to the case of non-isotropic scattering. The wave function in a medium of scatterers, averaged over the position of the scatterers, is found, as before, to obey a modified wave equation. The index of refraction and attenuation of the wave in the medium are shown to be determined by the scattering amplitude in the forward direction of a single scatterer. An integral equation is found for $\langle \psi^*(r)\psi(r') \rangle$, a quadratic in the field variables. This integral equation describes incoherent scattering effects. The notation has been generalized sufficiently to describe the scattering of quantized waves.

S7. Charge Conjugation in Two Component Wave Equations. HERBERT JEHLE, *University of Nebraska.*—The set of two component equations

$$\gamma^\kappa(\partial/\partial x^\kappa - i\varphi_\kappa)\psi = \mu\psi^*,$$
$$\tfrac{1}{2}(\gamma^{\kappa *}\gamma^\lambda + \gamma^{\lambda *}\gamma^\kappa) = -g^{\kappa\lambda}1,$$

admit the Lorentz group; but not reflections except in the trivial case $\varphi_\kappa = 0$. The solutions of these equations fall into two classes describing the motion of charges of opposite signs in a given field φ_κ. J. Serpe[1] and C. W. Kilmister[2] have recently commented on the covariance properties of this system, the matrices γ^λ have been extensively studied by O. Veblen several years ago.[3]

[1] Phys. Rev. **76** (1949).
[2] Phys. Rev. **76**, 568 (1949).
[3] Unpublished manuscript.

S8. Interaction Representation of General Fields. F. J. BELINFANTE AND J. S. LOMONT, *Purdue University.*—The possibility of a transformation to interaction representation was investigated for the most general first-order Lagrangian field theory in which the identities give the derived variables as uniquely determined sums of products of canonical variables and their derivatives but may contain interaction terms. In order to make the transformed variables ${}^\sigma q(x)$ point functions, it was necessary to let the space-like surface of transformation be tangent at x to the xyz-plane of the Lorentz frame in which $q(x)$ was measured. Also $W(x)$ appearing in the generalized Schrödinger equation $ihc\delta\Psi[\sigma]/\delta\sigma(x) = {}^\sigma W(x)\Psi[\sigma]$ consists of the interaction terms in the Hamiltonian energy-density evaluated in a Lorentz frame "tangent" to σ at x.

Under these conditions the integrability of this Schrödinger equation was proved. In interaction representation, in general not the ${}^{\sigma}q(x)$ form tensor-undors as the $q(x)$ did in Heisenberg representation. Instead, one has to replace the derived variables by new functions obtained by omitting all interaction terms from the identities, while the canonical variables are left unchanged. The new functions thus defined are tensor-undors in interaction representation satisfying field equations without interaction and satisfying the commutation relations for non-interacting fields.

S9. Elimination of the Self-Electromagnetic Field. STUART P. LLOYD, *University of Illinois.*—A non-quantized Dirac spinor field is in interaction with a classical electromagnetic field. Elimination of the electromagnetic field gives a non-linear equation for the stationary states of the electron wave function. A variational integral is constructed and a four parameter $J=\frac{1}{2}$ spinor is used as a trial function. There is a stationary point and the value $\hbar c/e^2=0.842$ is obtained. The total energy, matter plus coulomb, is negative and works out to be $-0.765\ mc^2$, where m is the coefficient of the matrix beta in the wave equation.

S10. Relation between *S*-Matrix and Hamiltonian. H. EKSTEIN, *Armour Research Foundation of Illinois Institute of Technology.*—The question has been raised recently whether the scattering potential $V(r)$ is uniquely determined by the S-matrix, and has been answered in the affirmative[1] for the case of a central force. An extended result, without restriction to central forces, can be obtained as follows: For sufficiently large particle momentum k_0, the R-matrix element is, by Born's approximation, proportional to $(k'|V|k^0)$ which is a function of $(k'-k^0)$ only. By joining two points of the surface $k'^2=k^{02}$, one can obtain any value of $(k'-k^0)$ and therefore, V is fully determined by the knowledge of the *asymptotic* form $(|k^0|\to\infty)$ of the S-matrix. This argument holds also for many-particle scattering and for relativistic equations. The observation that the asymptotic values of the S-matrix fully determine the potential has the implication that an arbitrarily chosen S-matrix will in general be incompatible with the existence of a potential. When the Hamiltonian is of a more general form, it cannot be shown that the asymptotic values of the S-matrix determine *all* values of the interaction Hamiltonian, but there will still be severe restrictions on the S-matrix if it is to be compatible with a Hamiltonian.

[1] V. Bargmann, Phys. Rev. **75**, 301 (1949); Rev. Mod. Phys. **21**, 488 (1949).

S11. Free Vibrations of An Isotropic Cube. T. SCHIFFMAN AND H. EKSTEIN, *Armour Research Foundation of Illinois Institute of Technology.*—Approximate solutions for free vibrations of an isotropic cube are derived by the perturbation method.[1] The modes are classified by group theory. Three rigorous degenerate modes are known.[2] Three longitudinal plane waves in the X, Y, and Z direction, respectively, are also solutions for the case of zero Poisson's ratio. These six functions are used as "zero order" modes. The operations of the cubic group are applied to these six zero-order eigenfunctions and the linear combinations which are the basis for the irreducible representations are determined. The modes are found to belong to the A_1, A_2, and $2E$ irreducible representations,[3] exhibiting the symmetric "breathing" mode, one rigorous mode belonging to A_2, two rigorous and two coupled modes belonging to the two-dimensional irreducible representation. Thus, the triple degeneracy is accidental. The corresponding frequencies are functions of Lamé's constants, λ and μ:

$$\rho\omega_1{}^2=2\mu k^2\left(1+\frac{\pi^2+16}{\pi^2}\frac{\lambda}{2\mu}\right),\quad \rho\omega_{2,3,4}{}^2=2\mu k^2,$$

$$\rho\omega_{5,6}{}^2=2\mu k^2\left(1+\frac{\pi^2+4}{\pi^2}\frac{\lambda}{2\mu}\right),$$

where $k\equiv\pi/\text{length of edge}$.

[1] H. Ekstein, Phys. Rev. **66**, 108 (1944); **70**, 76 (1946).
[2] H. Mähly, Helv. Phys. Acta **19**, 412 (1946).
[3] Notation as in Eyring, Walter, and Kimball, *Quantum Chemistry* (1944).

SATURDAY AFTERNOON AT 2:15

Kent Theatre

(B. WALDMAN presiding)

Apparatus of Nuclear Physics; Crystal Counters

T1. The Illinois Cyclotron Oscillator. G. F. TAPE AND P. G. KRUGER, *University of Illinois.*—The 11-mc oscillator now in operation on the University of Illinois cyclotron was chosen for simplicity of components and operation and for flexibility in changing frequency when changes of energy from the cyclotron are desirable. Two Type 880 power triodes are self-excited in push-pull operation. Following general designs of the Pittsburgh and M.I.T. oscillators, each tube is mounted directly over a concentric dee line. The inductive coupling loop feeding the dee line is connected directly to the plate of the tube. The two grids are coupled together by a single inductance coil. Thus the tank circuit of the oscillator is effectively the resonant circuit of the cyclotron and power is transferred without transmission lines. Water-cooling of tubes and loops is simplified by operating the plates at d.c. ground and leading the water in and out on the r-f ground side of the loops. The r-f measurements have shown the cold resonant frequency of the grid circuit to be about 1.3 mc above the operating frequency. Operation has shown that for reliable starting and for riding through load changes (gas bursts in the chamber) a large grid drive is necessary.

T2. The Pole Tips on the Carnegie Institute of Technology Cyclotron Magnet. MARTIN FOSS, *Carnegie Institute of Technology.*—The pole tips on the Carnegie Institute of Technology cyclotron magnet have complex contours, the surfaces of which near the outside radius have a series of ridges and valleys which rise above and below the average position. This structure enables the magnet to produce a higher energy proton beam than would otherwise be possible in a magnet with the same yoke, pole base, and coil. The scheme was suggested by the solution of a series of two-dimensional problems and the actual contour was determined by a cut-and-try procedure in which the field was measured to one-one-hundredth percent. Recently, a three-dimensional method for determining the potential associated with a given field has been developed. This may be applied to the design of poles for β-ray spectro-

graphs or other apparatus. This work was supported by the ONR.

T3. Voltage Stabilizer for Electrostatic Generator. W. C. MILLER, B. WALDMAN, J. C. NOYES,* AND J. E. VAN HOOMISSEN, *University of Notre Dame.*—The use of a tank liner (i.e., insulated shield enclosing entire column and terminal assembly) to stabilize the potential of an electrostatic generator has been suggested by several workers in this field. A partial linear has been installed in the Notre Dame generator. This liner is an aluminum cylinder eight feet long of four-foot radius, coaxial with the high voltage terminal, and is mounted between the terminal and tank. It is supported at a distance of two inches from the tank wall by Mykroy insulators. Because of the capacitive coupling between linear and terminal, a change of potential of the liner induces a proportional change in the potential of the terminal. The potential of the liner can be varied rapidly from 0 to 30 kv by an r-f-type power supply. This induces a change in the potential of the terminal of approximately 15 kv. An error signal from a generating voltmeter controls this power supply. Preliminary results indicate that a stability of better than ± 5 kv can be obtained with this method. This work has been partially supported by the Joint Program of the ONR and AEC.

* AEC predoctoral fellow.

T4. The Use of Selenium Rectifiers in a 500-Kev Generator. W. R. ARNOLD, *State University of Iowa.*—A 500-kilovolt linear accelerator recently placed in operation is described. This voltage is obtained by the use of a voltage multiplier circuit using selenium rectifiers and one-microfarad condensers in 22 stages. The input is nine kilovolts at 750 cycles, and the peak inverse voltage across each rectifier and condenser is 25 kilovolts. Because of the large condensers and relatively high frequency, the ripple should be less than 0.2 percent and the regulation appears to be quite good in spite of the large multiplication (44 times). The generator is capable of handling a one-to-two-milliampere total beam. The large number of stages allows use of lower voltage condensers and a series of constant voltage points to tie into an accelerating tube which eliminates the usual corona gaps.

T5. Fast Neutron Detector. W. G. MOULTON AND C. W. SHERWIN, *University of Illinois.*—A simple fast neutron detector suitable for health physics applications has been constructed using two 931A photo-multiplier tubes in coincidence to reduce background. A "sandwich" made of Lucite and activated zinc sulfide used for fast neutrons from a Ra-Be source is 1.5 ± 50 percent $\times 10^{-4}$. It detects a fast neutron flux of 20 neutrons/cm^2 sec. with a counting rate that is over ten times background. The counter has the advantage that by proper choice of discriminator bias it may be rendered essentially insensitive to gamma-radiation without an appreciable decrease of the neutron efficiency.

T6. Measurement of Fast Neutron Energies by Observation of $Li^6(n, \alpha)H^3$ in Photographic Emulsions. GEORGE R. KEEPIN, JR. AND JAMES H. ROBERTS, *Department of Physics, Northwestern University.*—A new technique of neutron energy measurement not requiring neutron collimation is described. The method employs the nuclear reaction $Li^6(n, \alpha)H^3$ (Q 4.64 Mev) observed within photographic emulsions impregnated with enriched Li^6. Results on monoenergetic neutrons indicate a resolution of at least ± 0.1 Mev in the region studied (from thermal energies up to 1.3 Mev). For this resolution, good discrimination between the alpha-particle and triton tracks is required. To extend the method for use as a precision neutron spectrometer suitable for continuous neutron spectra, both the excitation function and the angular distribution of the Li^6 disintegration process should be known. For immediate practical application both these measurements might be circumvented by calibrating the method with a well-known spectrum. The Li^6 method is particularly well suited to energy measurements on neutrons within a material medium where perturbations introduced by the detector must be minimized and where collimation is clearly impossible.

T7. Space-Charge Effects in Diamond Conduction Counters.* R. K. WILLARDSON, A. C. DAMASK, AND G. C. DANIELSON, *Iowa State College.*—The accumulation and removal of space charge in diamond counters has been investigated by McKay and by Newton for electron bombardment and by Ahearn for alpha-particle bombardment. Space-charge effects do not seem to have been reported for bombardment of diamonds with gamma-rays. We have investigated in some detail the variation in counting rate of several diamonds which count not only alpha-particles but also cobalt^{60} gamma-rays. Prior to the usual decrease in counting rate attributed to negative space charge from trapped electrons, we observe a conspicuous increase in counting rate which we interpret in terms of an accumulation of positive space charge. This effect is observed when counting gamma-rays, but has not been observed when counting alpha-particles. With increasing bombardment time the deeper traps become occupied. This is indicated by a decreasing counting rate recovery when the source is periodically removed. The space charge is removed by irradiation with light from a Nernst filament when using a gamma-source. This has been observed by Chynoweth[1] using alpha-particles.

* This work was performed in the Ames Laboratory of the AEC.
[1] A. C. Chynoweth, Phys. Rev. **76**, 310 (1949).

T8. Efficiencies of Calcium Tungstate and Calcium Fluoride as Scintillators for Low Energy Electrons.* WALDO RALL** AND R. G. WILKINSON, *Indiana University.*—Natural polished calcium tungstate crystals from Kern County, California, and synthetic calcium fluoride crystals from Harshaw Chemical Company were tested for their low energy response to beta-rays. A commercial 5BP1 tube was mounted in a vacuum system as an electron gun which could accelerate electrons up to 5600 volts. The electron beam which was operated between 10^{-10} and 10^{-12} ampere was monitored by passing it through an electrometer grid of about ten percent transmission placed just in front of the crystal. The 1P28 photo-multiplier tube was operated at -600 volt, which was also the potential placed on a secondary electron guard ring for the electrometer grid. Curves will be shown giving pulse-height distributions and efficiencies from 500 to 5600 volts. The absolute efficiencies are probably accurate within 50 percent, the relative efficiencies within 20 percent. The integral bias curves are logarithmic over three orders of counting magnitudes. The efficiencies for 5000-volt electrons are 10^{-4} and 5×10^{-4} for calcium fluoride and calcium tungstate, respectively, for pulses >120 microvolts.

* Supported by the ONR.
** Now at Yale University.

T9. Response of an Anthracene Counter to Monoenergetic Electrons of Energies 1.4, 2.2, and 2.6 Mev.* JAMES F. NORTON, *University of Rochester* (*Introduced by S. W. Barnes*). —By means of magnetic analysis a beam of monoenergetic electrons was obtained from a Sr+Y source. Curves of counting rate *versus* pulse height were measured for electron energies of 1.4, 2.2, and 2.6 Mev with a clear anthracene crystal of dimensions $\frac{3}{4}$ in. $\times \frac{1}{4}$ in. The scintillations were detected with a 1P21 photo-multiplier. The curves showed plateaus in all cases. The existence of a plateau and the value of the pulse height cut-off indicate uniformity and proportionality of the response. Such curves will be shown.

* Supported in part by the ONR.

T10. Proportional Counter Spectrometer.* C. J. BORKOWSKI AND E. FAIRSTEIN, *Oak Ridge National Laboratory.*—

The use of a proportional counter with high gas amplification for the determination of beta- and x-ray energies[1-3] has been used to examine the beta-ray spectra of C^{14}, S^{35}, Tm^{171} all of which have been previously examined with magnetic lens beta-ray spectrometers. The proportional counter used in this study was designed to give 50 percent geometry for solid samples. A sweep-type differential discriminator automatically plots the differential curve on a Brown recorder chart. The width at half-maximum of photo-electron peaks produced by 6.9-Kev x-rays is 17 percent. This resolution allows one to "resolve" adjacent elements in this part of the periodic table from their K x-rays.

* This document is based on work performed under contract for the AEC at Oak Ridge National Laboratory.
[1] C. J. Borkowski and E. Fairstein, "The use of a proportional counter for low energy beta-measurements," MonN-311, Oak Ridge National Laboratory Progress Report, March 1947.
[2] Curran, Angus, and Cockroft, Nature **162**, 302 (1948).
[3] Kirkwood, Pontecorvo, and Hanna, Phys. Rev. **74**, 497 (1948).

T11. Scintillation Studies on Potassium Iodide. M. FREEDMAN, B. SMALLER, AND J. MAY, *Argonne National Laboratory.*—Scintillation studies have been conducted on the effect of thallium impurity on the fluorescence properties of potassium iodide. Coincidence techniques have demonstrated the presence of single photon emission as expected from electron trapping at impurity sites. It has been possible to distinguish between the characteristic radiation due to the impurity and the fundamental or lattice radiation from the pure potassium iodide crystal. The fluorescence efficiencies of both types of emission have been determined as a function of temperature. Measurements of the K^{40} radioactivity in the crystal result in the values $\lambda(\beta)=3.92\times10^{-10}$ per year and $\lambda(\gamma)/\gamma(\beta)\cong0.04$. Comparison of pulse-height distribution with that from Cs^{137} activity gave a provisional $E_{max}(\beta)\cong1.3$ Mev.

SATURDAY AFTERNOON AT 2:15

Eckhart 133

(K. LARK-HOROVITZ presiding)

Semiconductors; Miscellany in Electron Physics

U1. Mobility of Electrons and Holes in Germanium. W. C. DUNLAP, JR., *General Electric Company.*—In a previous paper[1] the author presented results of a study of the conduction properties of high purity germanium. These measurements have been extended to cover samples from about three hundred ingots of germanium. Mobility values (R/ρ) as high as 4000 have been found for N type single crystals. Values as high as 3000 have been found for P type single crystals. These values are higher than those of Lark-Horowitz *et al.*, and of Pearson. It was found that higher Hall coefficients were obtained when point pressure contacts were used than when broad soldered or plated contacts were used. It was noted that high purity germanium annealed at 500–550°C has usually a low mobility figure (R/ρ), and thus is inhomogeneous, probably possessing a fine intermixture of N and P regions. It is also pointed out that the conduction properties of germanium also vary with time, and that the apparent mobility often decreases somewhat with time, even at room temperatures. It is concluded that only a lower limit on the mobility can be given from present Hall effect data.

[1] W. C. Dunlap, Jr., Phys. Rev. **71**, 471 (1947).

U2. Resistivity of Germanium Samples in External Magnetic Fields at Various Temperatures and Orientations.* A. FONER AND I. ESTERMANN, *Carnegie Institute of Technology.*—The effect of magnetic fields on the resistivity of isotropic conductors was first investigated by Gans[1] on the basis of a Maxwell-Boltzmann energy distribution for the conducting particles. In contrast to metals, the density of conducting particles in reasonably pure semiconductors is so low that they may be treated in accordance with classical statistics. Experiments were carried out with N and P type germanium samples at various temperatures between 20 and 300°K and with different angular orientations between electric and magnetic fields. In the case of a P type sample, the change in resistance as function of field strength and orientation was in fair agreement with theoretical results. The hole mobility was calculated to 1900 cm²/volt-sec. which is higher than calculated from Hall constant and conductivity, but in good agreement with Pearsons[2] value for single crystals. In N type samples, the observed effect is always several times larger than calculated, and does not disappear for longitudinal orientation. According to unpublished calculations by Seitz, the inclusion of anisotropic terms could produce the additional increase in resistance in all orientations.

* This work is supported by the ONR.
[1] R. Gans, Ann. d. Physik **20**, 293 (1906).
[2] G. L. Pearson, Phys. Rev. **76**, 179 (1949).

U3. The Reflectivity of Germanium Semiconductors. K. LARK-HOROVITZ AND K. W. MEISSNER, *Purdue University.*—The reflectivity of germanium alloys of the N type (electron conductor) and P type (hole conductor) has been investigated. Samples with a smaller number of carriers ($\sim10^{16}$/cm³) and with high impurity content ($\sim5.10^{18}$/cm³) were used.

In the range from 0.6μ to 12μ a rocksalt spectrometer and a Nernst filament as a radiation source were used. The semiconductor sample was mounted in exactly the same plane as a comparison aluminum mirror and the reflectivity determined for various settings of the spectrograph expressed in terms of the reflectivity of the aluminum mirror. Between 0.6μ and 0.8μ the reflectivity of all the samples is between 47 percent and 51 percent. The reflectivity then decreases and remains almost constant about 35 percent up to about 40μ. In the range from 8.7μ to 152μ the method of residual rays was used. Radiations selected from the incident continuous radiation with wave-length $\lambda=8.70\mu$, 20μ, 30μ, 41μ, 52μ, 117μ, and 152μ were employed. The highly conducting samples show a high reflectivity at 117μ which decreases again at 15μ, but is still considerably higher than the reflectivity of the high resistance samples which remains essentially constant through the whole wave-length range.

U4. Dependence of the Germanium High Back Voltage Rectifier Resistance on Frequency.* R. BRAY AND H. J. YEARIAN, *Purdue University.*—Germanium high back voltage rectifier units show anomalously poor rectification at high frequency. Detailed investigation,[1] involving measurement of the

rectified d.c. current for voltages of frequencies from 60 cycles to 60 mc showed the forward resistance to increase with frequency f, for $f \lesssim 100$ kc. The effect is small at low voltage, increases with voltage and becomes almost constant above 0.6 volts r.m.s. where predominantly spreading resistance determines the current. The effective back resistance at 1000 cycles and 30 mc were compared. It was found to be lower at 30 mc only when there was a forward swing to the applied voltage, otherwise it was higher. An interpretation is suggested in terms of the motion in the high frequency field of the holes injected into the germanium from the point contact. Thus for $f \lesssim 2/\tau$, (τ is lifetime of the holes), a decrease in the depth of penetration of the holes results which increases the spreading resistance. The back resistance can be decreased by the return to the contact, and the collection there, of the holes injected during the forward swing of the voltage.

* Work partially assisted by Signal Corps Contract.

[1] H. J. Yearian, "Dependence of forward conductance and back resistance of high back voltage germanium on voltage and frequency," NDRC Report (October 1945).

U5. Infra-Red Transmission of Germanium and Silicon.* M. Becker and H. Y. Fan, *Purdue University.*—In the investigation of photoelectric effects in germanium, it was found that these effects can still be observed when a piece of silicon or germanium several millimeters thick is interposed in the incident beam. This shows that infra-red transmission or absorption can be measured on bulk material instead of being measured on thin films or deduced from reflection measurements. Transmission measurements were made on germanium and silicon using slabs of thicknesses up to 15 mm. Germanium shows very little absorption from 12μ to 2μ, the transmission being determined primarily by reflection. The absorption coefficient is between 0.1 and 1 cm^{-1} for samples of resistivity $\rho \sim 5$ ohm cm and between 1 and 10 cm^{-1} for samples $\rho \sim 0.015$ ohm cm. It rises sharply at 2μ toward short wave-length. The absorption coefficient of silicon ($\rho = 0.03$ ohm cm) shows a minimum $\mu \sim 15$ cm^{-1} around 1.2μ at room temperature. It rises sharply toward short wave-length and more gradually toward longer wave-length. Measurements of silicon have been extended from liquid nitrogen temperature to 400°C. The absorption increases with increasing temperature with the minimum shifting toward longer wave-length. The reflecting power for polished surfaces is 0.35 for germanium and 0.27 for silicon.

* Assisted by a Signal Corps Contract.

U6. Resistivity at Boundaries Between Crystallites in Semiconducting Materials. V. A. Johnson, *Purdue University.*—It is found that the observed electrical resistivities of pure tellurium[1] samples and some silicon[2] samples at low temperatures are not accounted for theoretically[3] by the combination of only resistivity due to lattice scattering and resistivity due to impurity scattering. It is apparent, for these samples, that there exists an additional source of scattering characterized by a mean free path almost independent of temperature. An earlier study by Goodman[4] has described scattering of electron waves at crystallite boundaries as a source of electrical resistivity; this process is characterized by a mean free path dependent upon crystallite size and independent of temperature. The combination of such a resistivity due to scattering at crystallite boundaries with resistivities due to lattice and impurity scattering removes the discrepancy between theory and experiment mentioned above.

[1] Virgil E. Bottom, Phys. Rev. **75**, 1310 (1949).
[2] K. Lark-Horovitz, Contractor's Final Report, NDRC 14-585 (November, 1945), pp. 57-61.
[3] K. Lark-Horovitz and V. A. Johnson, Phys. Rev. **69**, 258 (1946).
[4] B. Goodman, NDRC Div. 14 Report, University of Pennsylvania (April 25, 1945).

U7. Dielectric Breakdown in Simple Non-Polar Crystals.* W. R. Heller, *Washington University.*—A treatment of the interaction of conduction band electrons with atomic lattice vibrations shows that breakdown in non-polar crystals may be grouped into three classes, *A*, *B*, *C*. Ideal crystals (with a relatively small number of shallow trapping centers) compose classes *A* and *B*, according as $h^2/8m\lambda_{min}^2 \lesssim I_{cr}$ where λ_{min} is the minimum wave-length of the sound quanta, and I_{cr} is the energy separation between the top of the filled band and the lowest conduction level. Class *A* is analogous, as regards breakdown criterion, to the ideal polar crystal treated by Frohlich, and permits the definition of only a lower limit to the actual breakdown field, F_A. Class *B* allows derivation of an actual breakdown field, F_B, but occurs only infrequently. Class *C* includes crystals in which impurities and lattice defects act as important ionizable centers (energy $I_i < I_{cr}$) and also yields (if only one type of trap is present) a unique breakdown criterion, F_C. As an example, a clear diamond (without absorption bands in the visible) and with centers of mean depth 0.75 volt should reach F_A at 136,000 volts/cm and F_C at 64,000 volts/cm, independent of temperature for $T \ll T_{Debye}$, the physical reason for the inequality $F_A > F_C$ being apparent from the theory.

* This work was done under the tenure of an AEC pre-doctoral fellowship and assisted by the Joint Program of the AEC and the ONR.

U8. Multiple Scattering of Electrons in Argon.* Fred L. Ribe, Martin J. Berger and Gerhart Groetzinger, *University of Chicago.*—The multiple scattering of electrons with energies from 50 to 1700 kev in one atmosphere of argon was measured by means of a magnetic cloud chamber. 132 tracks with a total path length of 1800 cm were examined. For each individual track the angles between successive chords connecting points two centimeters apart along the track were measured and from the mean and the mean square of these angles the most probable momentum and mean square angle of multiple scattering were determined. The experimental multiple scattering (as a function of the momentum) obtained from the measurement of the 132 tracks was compared with that predicted by the theories of (a) Bothe, (b) Williams, (c) Saunderson and Goudsmit, (d) Molière, and (e) Snyder and Scott. Theories (d) and (e), as well as (b) if an available parameter is suitably adjusted, give a root mean square angle of multiple scattering which agrees fairly well with that found by us. The maximum deviations (at the endpoints of the momentum range investigated) do not exceed 2.5 times the probable experimental error (~10 percent) while over most of the momentum range the agreement is within the limits of the experimental error.

* Assisted by the Joint Program of the ONR and the AEC.

U9. Radiation Transients in Brief Gas Discharges. R. G. Fowler, *University of Oklahoma.*—Abrupt discharge of a condenser through a gas has been investigated for effects of the type described by Rayleigh.[1] The discharge tube used was in the form of a *T*, with electrodes at the ends of the top. Subsequent to the discharge ($\sim 10^{-7}$ sec.) fronts of excitation and ionization have been detected passing down the stem of the *T* at velocities up to 2×10^6 cm/sec., and advancing up to 10 cm. Behavior of these fronts indicates strongly that they have the nature of powerful shock waves. Examination of the radiation emitted when hydrogen gas is used shows the Balmer line series and Balmer continuum in about equal intensities. Experiments show that the Balmer continuum is emitted within 10^{-8} sec. of the emission of the Balmer line series, and co-spatially. It is concluded that rapid recombination acts may proceed the emission of the line spectrum.

[1] R. J. Strutt (Lord Rayleigh), Proc. Roy. Soc. **183**, 26 (1944-45).

U10. On the Use of Coaxial Lines to Produce and Measure Short Time Delays.* DONALD C. MOORE AND WILLARD A. REENSTRA,** *Rensselaer Polytechnic Institute.*—Coaxial lines have been used as delay elements and pulse delays of 2.5×10^{-8} seconds have been produced and measured. Negative pulses of approximately 2.5×10^{-8} second in length and with an amplitude of 100 volts were generated with the discharge of a thyratron into a delay line with its end open circuited. These pulses were narrowed still further by clipping all but their extreme negative point with a biased germanium diode (1N48). These signals were then sent through two coaxial lines (RG 63-U) to a Rossi coincidence circuit and a coincidence was detected with a discriminator circuit. By measuring the difference in delay line necessary to produce or lose coincidence, it is possible to find the inherent resolving time of the circuits for pulses of such a shape. Some of the possibilities and limitations of the circuit as an instrument for the measurement of actual time delays will be discussed.

* Supported by the Rensselaer Polytechnic Institute Research Fund.
** Now at the Bell Laboratories, New York City.

U11. Electron Dynamics in a Standing Wave Accelerator. GERALD HOFFMAN AND EDWARD AKELEY, *Purdue University.*—The axial motion of an electron in a standing wave accelerator will be given by

$$du/dx = A\{\cos(t-x/V)+\cos(t+x/V)\},$$

and an equation for dt/dx. x represents the position of electron on axis, t time, u relativistic kinetic energy and V a mean wave speed. Certain natural units are used and A is a dimensionless constant proportional to longitudinal component of electric field strength. A synchronous particle is defined and the deviations of u and t as functions of x for an actual particle from those of the corresponding synchronons one are expressed as power series in the initial values of these deviations. The first- and second-order coefficients, expressed as power series in A have been computed through their second-order terms. This expansion makes possible a discussion of the energy and time distribution of those particles whose orbits do not differ too much from the synchronons. Graphs of u and t as functions of x have been obtained for the Purdue accelerator.

SATURDAY AFTERNOON AT 2:15

Breasted Hall

(L. A. TURNER presiding)

Invited Paper on Solid-State Physics

V1. Stability of Color Centers in Alkali-Halide Crystals. P. PRINGSHEIM, *Argonne National Laboratory.* (30 min.)

Papers Not Classed Elsewhere

V2. Time Delays for Plastic Flowing. JOHN KAUFFMAN AND WALLER GEORGE, *Naval Research Laboratory.*—Under suitable conditions, appreciable time intervals are observed between the application of a load and the response of a solid to this load by plastic flowing. These time intervals are termed delay times, and appear to have been first systematically studied by Clark and Wood in mild steel.[1] The phenomenon will be demonstrated in polymeric films. The delay time in Nylon films is found to vary slowly with applied stress, from 1 to 10^3 sec. for stresses between 4400 and 3000 p.s.i., with an apparent activation energy of about 120,000 cal./mole. Similar effects are found in polyethylene films. Under dead-weight loading, the flowing appears after the time delay, as one or more severe localizations or "necks" which, in turn, propagate slowly along the specimen with the evolution of heat. The macroscopic phenomenological similarities between delay times in mild steel and high polymers will be discussed.

[1] D. S. Clark and D. S. Wood, Proc. A.S.T.M. Preprint No. 25 (June, 1949).

V3. Multiple Diffuse Small Angle Scattering of X-Rays.* D. L. DEXTER AND W. W. BEEMAN, *University of Wisconsin.*—The problem of multiple x-ray scattering from spherical particles of radius much larger than the wave-length ($a/\lambda\sim10^2$ or 10^3) is treated using the Guinier approximate scattering function.[1] The total coherently scattered intensity is found to be a sum of Gaussians in the polar angle with coefficients dependent on the sample thickness. A method is discussed for determining particle sizes from the variation of the width of the scattering curve with sample thickness in the region of high multiplicities ($\gtrsim10$). Experimental radii of Godfrey L. Cabot P-33, Sterling L, and Spheron Grade 6 carbon blocks are 770, 480, and 180A, respectively. The results for P-33 and Grade 6 are in better agreement with weighted average radii obtained from nitrogen adsorption and electron-micrograph data[2] than with sizes obtained from the usual log of intensity *versus* angle squared curves. This method may be useful for particles too large to be treated by standard single scattering techniques.

* Assisted by the ONR and the Wisconsin Alumni Research Foundation.
[1] A. Guinier, Ann. de physique **12**, 161 (1939).
[2] Anderson and Emmet, J. App. Phys. **19**, 367 (1948).

V4. Direction-of-Fall of Sedimenting Particles. E. E. MILLER AND C. B. TANNER, *University of Wisconsin.*—Kunkel has recently reported[1] that unsymmetrical particles drift to one side in falling through viscous media. Such behavior would invalidate most sedimentation methods of determining particle-size distributions. Since Kunkel used only a few special shapes and was concerned with charge-analysis of dusts, a simple experiment was devised for testing naturally occurring particle shapes. A continuous but dilute stream of particles was injected from a point at the top of a motionless, thermally stabilized body of water. After some hours of operation, the accumulation of particles on the bottom of the container was examined. Qualitatively, it was noticed that most natural particles actually do plane to one side when falling, but at the same time they rotate. The result is a small regular spiral about a vertical axis. Quantitatively, the experiment showed that sideward drifts can be neglected for normal sedimentation equipment. Soil samples showed less dispersion than powdered mica, which suggests a possible method for shape-factor analysis.

[1] W. B. Kunkel, J. App. Phys. **19**, 1056 (1948).

V5. Some New Techniques in the Calorimetry of Solids,* MALCOLM DOLE, JOHN A. WETHINGTON, JR., NORMAN LARSON AND W. P. HETTINGER, JR., *Northwestern University.*—In setting up an apparatus for the measurement of specific and latent heats and heats of transition of solid high polymers we have been led to develop an automatic device for adiabatic temperature control which may be of interest to workers in the field of calorimetry. We also make use of a special watt-hour meter for the estimation of the electrical energy input which simplifies the operation of the equipment. The introduction of continuously recording potentiometers enables us to correct the observed rises in temperature for any inequality in temperature between the calorimeter and its adiabatic jacket. Furthermore, our automatic equipment not only makes possible a quantitative study of the effect of gas pressure and other factors on the temperature drifts of the calorimeter with time, but also is especially adaptable to the measurement of slowly occurring heat effects. We hope to present a short moving picture sequence of the calorimeter apparatus in actual operation.

* This work was aided by grants from the Visking Corporation, E. I. Du Pont de Nemours and Company, The Richardson Company, and the Research Corporation (Frederick Gardner Cottrell Grant). R. C. Wilhoit and A. E. Worthington assisted in some of the measurements.

V6. Distribution of Phases in Two-Phase Solids. LEONARD D. JAFFE, *Watertown Arsenal.*—The quasi-equilibrium distribution of a disperse phase, B, within a polycrystalline second phase, A, is investigated by methods of statistical thermodynamics. Phase B is assumed to consist of spherical particles of uniform size within the A crystals, and of lenticular particles of uniform size at the boundaries between two A crystals. The concentration (Mf) of B at the grain boundaries of A is found to be related to the sizes (r_1 and r_2) of the B particles at and away from grain boundaries, in terms of the interfacial energies (γ_{aa} and γ_{ba}), the temperature (T), the over-all concentration (M), and the size of the A crystals (R), by

$$\left(\frac{Mf}{1-Mf}\right)\left(\frac{Mw}{1-Mw}\right)^{-r_1^3/r_2^3} = \exp\left\{-\frac{\gamma_{aa}r_1^2}{kT}\left[\frac{9\pi Z-\left(\frac{9\pi}{2}\right)^{\frac{1}{3}}(3Z^3+2\pi)\frac{r_1}{r_2}}{3Z^3-4\pi}\right]\right\},$$

where

$$w=1-\frac{2.66fr_1}{R\left(Z-\frac{\pi}{3}Z^{-2}\right)} \quad \text{and} \quad Z=\left[\frac{2\pi\left(4\frac{\gamma_{ba}}{\gamma_{aa}}+1\right)}{3\left(2\frac{\gamma_{ba}}{\gamma_{aa}}-1\right)}\right]^{\frac{1}{3}}.$$

Temperature will significantly affect the distribution only if $\gamma_{aa}r_1^2$ is of the order of kT, or if $\gamma_{ba}/\gamma_{aa}\sim\frac{1}{2}$.

V7. Thermodynamic Functions of Crystals from the Moments of the Frequency Distribution.* WILLIAM J. TAYLOR, *The Ohio State University.*—Montroll[1] has proposed the expansion in Legendre polynomials of the distribution function $g(\nu)$ for the frequencies (ν) of normal modes of vibration of a crystal, and has related the coefficients of the expansion to the even moments of $g(\nu)$. This expansion has the disadvantage that in practice, when only a few terms of the series are retained, a non-vanishing value will in general be obtained for $g(0)$, whereas for all crystals $g(\nu)$ must approach the Debye form, $g(\nu)\propto\nu^2$, for small ν. This difficulty may be overcome in a simple way by expanding the quantity $\nu^{-2}g(\nu)$ in even Legendre polynomials; the coefficients then involve also the second *inverse* moment of $g(\nu)$. Substitution of this expansion in the definite integral defining a thermodynamic function (integrand a product of $g(\nu)$ by an Einstein function), yields a convergent series of functions (of temperature) with coefficients depending on the moments of $g(\nu)$. The first of these functions is the familiar Debye function—a point in favor of the modified expansion proposed here. Tabulation of succeeding functions will make possible the calculation of higher order corrections to the Debye value directly from the moments of $g(\nu)$.

* This work was supported in part by the ONR under contract with the Ohio State University Research Foundation.
[1] E. W. Montroll, J. Chem. Phys. **10**, 218 (1942); **11**, 481 (1943); **12**, 98 (1944).

V8. A New Piezoelectric Effect. A. E. BENFIELD, *Harvard University.*—It seems likely that a stress gradient in a metal will produce a small separation of the electric charge in its interior, and a consequent small potential gradient, in a manner somewhat similar to that caused by a temperature gradient in the Thomson effect of thermo-electricity. Attention is drawn to this, and to the possibility of measuring it, since the effect does not seem to have been directly observed. Its existence has recently been predicted theoretically[1] by considering the maximum energy of the electrons in the Fermi-Dirac gas of a metal under appreciable hydrostatic compression. P. W. Bridgman, in measuring the Peltier heat between a number of compressed and uncompressed metals,[2] has apparently studied a closely related effect. The observed values of the Peltier heat are, however, many times smaller than would be expected from the above-mentioned theory; it is not entirely clear to what extent the observations correspond with the ideas presented here.

[1] A. E. Benfield, Phys. Rev. **75**, 211 (1949).
[2] P. W. Bridgman, Proc. Am. Acad. **53**, 269 (1918).

V9. Characteristics of Piezoids with Surfaces of Cylindrical Shape.* CHARLES R. MINGINS, CARL A. STEVENS, AND ROBERT W. PERRY, *Research Laboratory of Physical Electronics, Tufts College.*—In a previous paper[1] was described a method of studying the vibrational characteristics of a piezoid by a method of probing, employing the response spectrometer developed in this laboratory several years ago.[2] The work previously reported involved quartz plates with surfaces of spheroidal shape, with the vibrational effects of which this laboratory has been concerned for some time. The investigations presently discussed concern plates having major surfaces which are cylindrical in shape, where with something of the anatomy of surface shape influences can be studied. It is found that the 1,1,3 and 1,3,1 modes of the thickness-shear family can be placed in radically different spectral positions relative to each other and to the main response, and by varying the orientation of the cylinders further unusual effects can be obtained, such as the inhibiting of certain flexures and the selective use of portions of the plate.

* This work is sponsored by the Frequency Control Branch of the Signal Corps.
[1] Mingins, Stevens, and MacLeod, Phys. Rev. **76**, 467 (1949).
[2] C. R. Mingins *et al.*, Reports to U. S. Army Signal Corps (1944 ff.).

V10. Measurement of Small Curvatures by Optical Interference.* HAROLD R. LETNER, *Mellon Institute.*—The curvatures of nearly flat, specularly reflecting surfaces can be measured with good precision by means of optical interferometry. A simple instrument for producing and photographing the interference patterns is described and a method of obtaining highly magnified profiles of the surface directly from the resulting photographic negatives is illustrated. The method is applicable to the study of residual stresses of the type encountered in: (1) machining, grinding, lapping, honing, or shot-peening; (2) heat treatment; (3) differential thermal expansion; (4) electrodeposition; (5) shrinkage of protective coatings; (6) polymerization of plastic films.

* A contribution from the L. Leslie Byers Memorial Fellowship sustained at Mellon Institute by the Grinding Wheel Institute.

SUPPLEMENTARY PROGRAMME

SP1. Electrostatic Potential Energy of Crystals and Molecules from X-Ray and Electron Diffraction Data.* WILLIAM J. TAYLOR, *The Ohio State University.***—Methods for calculating the electrostatic potential energy of ionic crystals have been developed by Madelung, Ewald, Born, and others.[1] The method of Ewald, involving the Fourier expansion of the charge and potential functions, may be extended to the general crystal, thus obtaining an exact expression for the electrostatic energy in terms of the structure factors for positive and negative charge.[2,3] The latter may be calculated from assumed atomic functions or obtained from x-ray diffraction data. This method has also been extended to molecules, in which case the energy may be expressed in terms of the Fourier transforms of the radial charge density functions, which determine the molecular diffraction of x-rays and electrons.[3] The electrostatic energy is equivalent to the quantum-mechanical coulomb energy of the method of one-electron wave functions, if the latter is written in the symmetrical (unprimed) form, and represents the limiting value of this coulomb energy for an exact wave-mechanical calculation.

* This work was supported in part by the ONR under contract with the Ohio State University Research Foundation.

** To be given at the end of Session V if the Chairman rules that time permits.

[1] *Handbuch der Physik*, second edition, Vol. 24, Part 2, p. 705.

[2] C. N. Wall, Phys. Rev. 36, 1243 (1930), has given a rather obscure derivation of this relation, which has apparently been overlooked in the subsequent literature.

[3] Tech. Report No. 2, ONR Project NR 019 113 (June 15, 1949).

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